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ABSTRACT

The system of funding mechanisms through which the federal government supports research performed in universities is reviewed. Problems in the system and conclusions/recommendations for its improvement are discussed. The historical development of federal government interest in support of research, particularly research performed in universities, is described. Funding mechanisms used to support academic research, the views of government and research universities about the funding practices, and the issue of university-based research centers and their potential effects on the character of the research universities are considered. Among the problems in the current system of funding mechanisms are a rapidly developing equipment inadequacy problem, inadequate provision for new research initiatives and for sustaining research capacity, and erosion of institutional support for research in the humanities and social sciences. (SW)

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FUNDING MECHANISMS:

Balancing Objectives and Resources in University Research

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National Commission on Research

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NATIONAL COMMISSION ON RESEARCH
Funding Mechanisms: Balancing Objectives and Resources in University Research

Executive Summary

For the better part of a half century, the Federal government and the research universities of the nation have been associated closely in the support and performance of research. Recently, this relationship has become strained. The partners have developed different views on the objectives of their association and the conditions of their collaboration.

The Commission

The National Commission on Research was formed in late 1978 as an independent body. It was sponsored by interested organizations and supported principally by private foundations. The Commission was charged to study the relationship between the government and the research universities, to determine the nature and origins of the problems afflicting the relationship, and to recommend ways to solve these problems. Additional information on the origins and purposes of the Commission is contained in the Foreword (p. ix).

Funding Mechanisms

The mechanisms through which the Federal government supports research performed in universities are operational embodiments of government policies. The success of the government-university research partnership depends critically on the degree to which these funding mechanisms are properly suited to the policies, purposes, and expectations of both partners. In this document, the Commission surveys the system of funding mechanisms currently in use, identifies problems in the system, and presents conclusions and recommendations for its improvement.

The Introduction (p. 1) describes the historical development of Federal government interest in support of research, particularly research performed in universities. The next section (p. 5) provides an overview of the system of funding mechanisms currently used to support academic research and describes the strengths and weaknesses of the system from the points of view of the government and the research universities. Next, specific problems in the current system of funding mechanisms are described (p. 15), including difficulties in the array of funding mechanisms and difficulties in the funding instruments which are a part of the mechanisms. Also discussed is the growing issue of university-based research centers and their potential effects on the character of the research universities (p. 23). Next, the Commission's conclusions are presented (p. 25). The final section contains an explanation of each recommendation (p. 29).

Conclusions

The Commission derived several conclusions from its study (p. 25).

1. *Essential Elements.* Several key elements are essential to effective functioning of the research support system, including agreement about purposes, diversity, and provision for new ventures and sustaining research capacity.
2. *Character of Agreements.* Government-university research agreements should include appropriate characteristics such as tailoring to the nature of the performer as well as the sponsor, and utilizing the predominant mode of assistance rather than procurement.
3. *Problems.* While the current funding mechanisms are basically sound, significant unresolved problems remain.
4. *Continuing Experimentation.* An effective system of mechanisms must adapt to changes in the needs and the environment. Revisions and experiments with improvements should be undertaken regularly.

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5. *Mismatched Expectations.* A small number of policy issues remain a frequent source of mismatched expectations, particularly at the operating level. These include the appropriate means for developing research personnel and cost sharing by sponsors and recipients.

6. *Complexity.* The government-university research enterprise is so complex and varied that problems can be oversimplified and solutions misjudged. Care is required in developing changes which will attain intended benefits.

7. *Forum.* The preliminary suggestion made earlier by the Commission of a Forum of individuals concerned with the government-university research relationship has been well received. Further discussion to refine the concept is needed among interested parties.

Recommendations

1. *Equipment Obsolescence*
   The Commission recommends that the federal agencies and the universities adapt funding mechanisms and improve priority-setting strategies to solve the growing problem of research equipment obsolescence.

2. *Stability, Continuity, and Flexibility*
   The Commission recommends that Congress and the federal agencies develop and implement means to increase the stability, continuity, and flexibility of research support while retaining the capacity to respond to changing national priorities. The Commission offers several specific recommendations to this end:
   (a) The Commission recommends that Congress consider making a transition to a two-year appropriation cycle for those agencies and components of agencies which support basic research.
   (b) The Commission recommends that those agencies and components of agencies which support basic research lengthen the average duration of their basic research support agreements to at least two and preferably three years, if they have not already done so.
   (c) The Commission recommends that agencies experiment with authorizing program officers to award a limited number of non-renewable extensions of support at approximately the same level, without full renewal proposal submission and peer review.
   (d) The Commission recommends the introduction of incentives for funding agencies to provide more timely notices of awards.
   (e) The Commission recommends that agencies which fund large research programs build in forward-funding mechanisms or devise new ways to cushion the impact of termination of support.

3. *Research Capacity and Initiatives*
   The Commission recommends that the government and the universities work together to develop or adapt a funding mechanism to sustain the research capacity of universities, especially their capacity to undertake new research initiatives.

4. *Assistance As the Predominant Approach*
   The Commission recommends that the Federal government and the universities adopt the policy that assistance rather than procurement is the appropriate mode for support of university research, except where unusual circumstances specifically justify the use of the procurement mode.

5. *Experimentation with Mechanisms*
   The Commission recommends experimentation with new concepts in funding mechanisms as the government-university research relationship evolves. In particular, the Commission recommends experimentation with grants-in-aid managed at the local level.

6. *Cooperation within Institutions*
   The Commission recommends that the universities and the government seek ways to promote intra-institutional cooperation in all aspects of research operation. The Commission offers some specific recommendations toward this objective:
   (a) The Commission recommends that Congress authorize and the agencies develop arrangements for aggregating research projects for post-award administrative purposes.
   (b) The Commission recommends that the universities make concerted efforts to reduce internal friction and misunderstanding about indirect costs through education and full discussion of issues.
   (c) The Commission recommends that the method used by the National Institutes of Health for reimbursing indirect costs be adopted by the National Science Foundation and other agencies which interact significantly with universities.

7. *Cost-Sharing and Matching Requirements*
   The Commission recommends that Congress, the agencies, and the universities reexamine the rationale for cost-sharing and matching requirements in federal programs for support of research in universities to assure that any such requirements are constructive in furthering the mutual objectives of the government-university research relationship.

8. *Additional Science Indicators*
   The Commission recommends that the Office of Science and Technology Policy and the National Science Foundation (a) develop, employ, and report additional science indicators which reflect the balance and diversity of federal research funding programs and (b) encourage the general use of these indicators in research policy development and planning by government and universities alike.

9. *Growth of Research Centers and Institutes in Universities*
   The Commission recommends that the research universities, individually and collectively, examine carefully the implications for university development, structure, and governance of the growth of university-associated research centers and institutes.

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FUNDING MECHANISMS:

Balancing Objectives and Resources in University Research

National Commission on Research

May 1980

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Foreword

The National Commission on Research is a private, nonprofit organization established to examine the relationships between government agencies and universities involved in research and to develop specific recommendations for improvements. The Commission was founded in the latter half of 1978 by the American Council on Education, the American Council of Learned Societies, the Association of American Universities, the National Academy of Sciences, the National Association of State Universities and Land-Grant Colleges, and the Social Science Research Council. The Commission works independently of its founders to examine the process by which the Federal government supports academic research and to propose changes designed to improve that process.

Funding has been obtained for Commission activities to pursue this task from the following organizations: Carnegie Corporation of New York, Exxon Education Foundation, Ford Foundation, the William and Flora Hewlett Foundation, the Andrew W. Mellon Foundation, the National Science Foundation (Grants Nos. PRM-7903778 and CDP-7926386), the U.S. Department of Energy (Grant No. DE-FG01-80ER10167) and the Air Force Office of Scientific Research (Grant No. AFOSR-ISSA-80-00030). Over three-fourths of the funding was made available by the five private agencies and approximately one-fourth from the public sources. Any opinions, findings, conclusions, and recommendations expressed in this publication are the sole responsibility of the Commission and do not necessarily reflect the views of any of the aforementioned funding sources or founders.

This publication on funding mechanisms is the second in a series of documents to be developed by the Commission to analyze the process of government funding and university involvement in research and to make recommendations to all affected parties for improvements in the system. Subcommittees of the Commission are investigating each of the following issues:

(1) Accountability;
(2) Peer review and other selection processes;
(3) Alternative funding mechanisms;
(4) Industry/university/government relationships; and
(5) Development of research personnel.

Position papers on each topic will be published by the Commission.

The members of the Subcommittee on Alternative Funding Mechanisms are Dale R. Corson, Chairman; Donald N. Langenberg; and Linda S. Wilson.

In addition to surveying the available literature, subcommittee members and staff meet with selected officials from business, government, and the universities. At monthly meetings, invited speakers present their views on pertinent aspects of the listed topics or on the broad purview of the Commission. The Commission has received testimony on five university campuses from faculty members and administrators, as well as written comments stemming from invitations to research universities and from an open letter in *Science* magazine. Liaison with numerous government agencies is maintained through telephone contacts, correspondence, and attendance at Commission meetings. Approximately one hundred fifty persons have given advice and information to assist the Commission in its study thus far. The Commission appreciates the efforts of all the participants in its deliberations and discussions. A description of these considerations and a partial list of individuals are contained in the Appendix.

The members of the Commission are listed inside the front cover. These individuals have backgrounds in education, business, and government. They have accepted appointments to serve on the Commission without compensation. During Commission deliberations, they reflect their own experience and not necessarily the viewpoints of their institutions or organizations.

Liaison persons have been designated to the Commission by the following government agencies: Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA); Department of Defense (DOD); Department of Energy (DOE); Department of Health, Education, and Welfare (DHEW); General Accounting Office (GAO); National Aeronautics and Space Administration (NASA); National Institutes of Health (NIH); National Science Foundation (NSF); Office of Management and Budget (OMB); and Office of Science and Technology Policy (OSTP).

In its series of publications, the Commission will review the key elements of the present state of federally supported university research, affirm what it believes to be good in this system, analyze problem areas, and provide suggestions for actions to alleviate these problems. The Commission recognizes that much diversity

exists in the complex relationships among principal investigators, research administrators, and others in the university community, and program officers, auditors, administrators, and other government personnel. There is a wide range of beneficiaries, including industry, students, and the general public. The goals of the participating government organizations and educational institutions and of the concerned individuals involved in federally supported research are diverse and sometimes overlapping but not identical. Therefore, the Commission does not anticipate the ability to establish consensus on all of the issues. The Commission does seek to make a contribution to improved research in our nation by improving a system which produces a major portion of that research.

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Introduction

The United States government has played an active and often strongly debated role in the encouragement and support of research since the earliest days of the Republic.[1] The subject was discussed at the Constitutional Convention, with the result that the Constitution empowers Congress to "promote the Progress of Science and useful Arts," but then appears to narrow that power by specifying how, ". . . by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries."

In 1803, Congress appropriated funds in the amount of $2,500 to support a multidisciplinary investigation of the upper Missouri River. One of the project's principal investigators, Meriwether Lewis, broadened his expertise in preparation for the expedition by studying celestial navigation, zoology, botany, and ethnography with the learned members of the American Philosophical Society in Philadelphia. The Congress was evidently persuaded of the potential value of this study by President Jefferson's argument that it was "for the purpose of extending the external commerce of the United States," while at the same time being assured that this foray into foreign territories would be viewed by Spain and France as a mere "literary pursuit." To the Spanish minister Jefferson asserted that the expedition would "have no other view than the advancement of geography," while noting that in presenting his proposal to the Congress it would be necessary to "give it the denomination of mercantile, inasmuch as only in this way would Congress have the power of voting the necessary funds; it not being possible to appropriate funds for a society, or a purely literary expedition. . . ." Congress' rather modest direct appropriation was not the whole of the project's federal support; salaries and supplies were provided by the War Department.

Readers familiar with the research enterprise of the United States today will be struck by the way in which this early example of federally supported scientific exploration presages certain features of the modern scene. There is the use of expert advice from non-government scientists, the justifications in terms of practical benefit to a wary Congress and of scientific benefit to other interested parties, and the participation and support of a military service in the pursuit of objectives transcending any purely military mission. Additionally, there is the retrospectively evident importance to the nation of an exploration which before the fact must have seemed to many to be a frivolous waste of public money.

Other salient features of today's national research effort can similarly be traced to early origins. The Army and the Navy played prominent parts in the exploration of the continent and of the seas around it and sporadically supported science in support of their missions throughout the nineteenth century. In 1863, the National Academy of Sciences was founded, espousing as one of its purposes the bringing of science to the service of the government. A year earlier Congress had passed the Morrill Act, "donating public lands to the several States and Territories which may provide colleges for the benefit of agriculture and the mechanic arts." In 1887, Congress followed with the Hatch Act, providing federal support for agricultural experiment stations associated with the land-grant colleges developed as a result of the Morrill Act. These two legislative actions for the first time established the Federal government as a partner with academic institutions in a broad-based program to enhance the national welfare through research. The fruits of this century of partnership are no less astounding for being taken for granted by most American citizens. It has given the United States its original and perhaps most bountiful technology, American agriculture, which leads the world and is a major source of national strength.

The advent of the twentieth century brought a quickening of the pace of federal involvement in the support and performance of research. Two milestones among many are the establishment of the National Bureau of Standards in 1901 and the transformation of the Public Health Service's Hygienic Laboratory into the National Institute of Health in 1930. By the outbreak of World War II, the Federal government had become a major factor in the American research enterprise. The striking successes of that enterprise during the war are a familiar story. They led, after the war, to renewed public debate of the nature of the federal responsibility for support of scientific research. The character of this debate owed much to Vannevar Bush's eloquent arguments for the importance of public support for science and scientific institutions, presented in his report to the President, *Science—The Endless Frontier*. The debate resulted in the creation of the National Science Foundation in 1950.

The three decades since 1950 have brought an explosive expansion of federally performed and supported research. The nation currently invests about $50 billion (about 2.2 percent of the Gross National Product) annually in research and development (R&D); of this about half comes from the Federal government. Basic and applied research (the R in R&D) typically account for one-third of total national R&D expenditures; about two-thirds of the research total is for applied research, one-third for basic research.

One of the most significant features of the development of the national research effort since World War II is the emergence of the research universities as the principal performers of basic research. This was not accidental or unintended, but the result of conscious national policy decisions epitomized by the creation of the National Science Foundation with its mission "to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences; and to initiate and support basic scientific research in the mathematical, physical, medical, biological, engineering, and other sciences. . . ." The research universities had embraced research as one of their principal missions since the latter part of the nineteenth century but, with the exception of agricultural research, had pursued this mission independent of any substantial government support before the late 1940s.

Today the situation is very different. The research universities of the nation number 50 to 150, depending on the criteria used. These institutions account for only about 10 percent of total national R&D expenditures but more than 50 percent of total national expenditures on basic research. The basic research figure rises to 60 percent if expenditures by federally funded research and development centers (FFRDC's) administered by universities are included. About three-quarters of the funds spent by universities on basic research are provided by the Federal government. Thus, over the last three decades the United States has moved purposefully to vest the greatest share of the responsibility for the creation of new knowledge, the seedbed of future technology, in a government-university partnership.

It is important to understand that this partnership is neither simple nor inevitable. On one side, there is the Federal government embodied in a diverse array of agencies, each with its own mission and its own perspective on the purposes of research. On the other side, there is a diverse array of research universities, some private and some public, but none a federal institution. With few exceptions, every agency and every university has functions, obligations, and constituencies which have little to do with the research which is the common concern of the partnership. This arrangement is almost uniquely American. Other countries have taken different paths. In most, all universities are government institutions and in many, institutions of the central government. In many, the system of basic research performers includes and is often dominated by publicly supported research institutes more or less unrelated to any university.

Any serious contemplation of the American system for the investment in and conduct of research and development raises many questions and issues. The federal role in this system particularly highlights these aspects. Few are new, and many first appeared in the earliest days of the nation. Among them are:

- Does the Congress have the power to provide funds in support of research? This constitutional question was actively argued in the early decades of the Republic. It appears to have been settled in the affirmative.
- Should Congress provide funds in support of research? This question also appears to have been settled in the affirmative, but more recently, and consensus on the question is far from complete.
- For what purposes should Congress provide funds in support of research?
- At what level should Congress provide funds in support of research?
- What is the best balance among basic research, applied research, and development?
- What is the best balance among different fields of science and technology?
- What is the best balance among federal agencies?
- What is the best balance among types of research performers?
- What is the best balance among types of support, e.g., support for specific projects, broad programs, institutions, or training of individuals?
- What should be the nature of the funding relationships between the Federal government and research performers?

All but the first of these questions have long been and can be expected to remain active subjects of national debate. The purpose of this report is to examine some of them in the context of a single element of the national research and development enterprise, the government-university partnership which has assumed the major responsibility for basic research. The report further focuses on one aspect of the partnership, the mechanisms through which the government provides and the research universities use public funds to support and perform research. It does so because these funding mechanisms are the operational embodiments of government policies

toward university research. The success of the government-university research partnership depends critically on the degree to which the funding mechanisms are properly fitted to the policies, purposes, and expectations of both partners

Over the past decade a variety of pressures and problems have led to increasing strain in the partnership. As detailed in the Foreword (p. ix), the independent National Commission on Research was established to review the state of the government-university research system and to seek ways to relieve the strains which have evolved. This report is the distillation of Commission thought on the issue of funding mechanisms and its bearing on the problem of reducing the strains and making the system more effective.

In the next section, the system of funding mechanisms currently used to support academic research is reviewed and comments are made on strengths and weaknesses of the various mechanisms from the points of view of the government and the research universities. This is followed by an examination of problems and issues in this system. The essential features of a good funding mechanism are described, as viewed by the Commission. The report then states conclusions of the Commission which identify ways in which the system can be improved and presents a series of recommendations for implementing the necessary changes.

Current System of Funding Mechanisms

An Overview of the System

Funding Mechanisms

In the years since World War II, many different mechanisms for the support of academic science have evolved, and many different federal agencies now participate in that support. The Commission has collected data about the forms of support used by various agencies and the amount of support by agency and by mechanism. It is important to collect such data and to analyze support by various agencies as the Commission has done because the relative emphasis placed by the various agencies on the differing forms of support is a statement of federal research policy. For example, to the extent that an agency has as its primary objective the strengthening of basic science and the support of individual scientists, the small research grant will be prominent. On the other hand, where the emphasis is on specific technological goals and the application of science and technology to societal problems, there will be greater reliance on research contracts and the support of research centers built around specific objectives.

Table I* shows the federal funds expended for university-performed research and development in Fiscal Year 1979. These are classified by agency source and by type of funding mechanism. There are listed below the six general mechanism types in our classification scheme.

Individual Research Projects

In this type, grant or contract awards are made to support work by a small number of investigators, often a single person. Awards are normally made to the investigator's university and are typically small relative to awards made through other types of funding mechanisms. This classification sets a rather arbitrary upper limit of $150,000 per year in defining an award as an individual research project. Such awards are based on proposals made by one or a few principal investigators. The research objectives are usually defined by the investigator rather than by the agency, and proposals are commonly evaluated through a peer review system. Most project research is performed within disciplinary departments of a university. Individual research project support accounts for almost half of all federal support for university research and development. Most of the work supported by this mechanism is basic research.

Research Programs

Where federal support is for a broad, coherent area of investigation, usually involving more than one senior investigator, and where the annual support exceeds $150,000, we have classified the support in this category.

Research Centers

Many agencies support university research organizations called "research centers" which undertake a research program in a particular, broad field of interest to the university and to a sponsoring agency. (The Categorical Disease Centers supported by the National Institutes of Health are an example.) The management of the center and coordination of specific research projects into a coherent research program are delegated to the university. Proposals for specific research projects carried on in the center may or may not be reviewed or approved individually by the federal agency.

Research on Problems Set by a Federal Agency

Federal agencies often identify areas within which they wish to have research or development performed and then seek proposals from prospective performers. The research is often of an applied nature, and the specification of the work to be performed is usually more tightly drawn than is the case in research centers. The support instrument is usually a contract rather than a grant.

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*The Commission is indebted to Dr. Charles V. Kidd of The George Washington University for help in compiling these data.

TABLE I:
FEDERAL FUNDS EXPENDED FOR UNIVERSITY RESEARCH BY AGENCY AND BY TYPE OF SUPPORT, FY 1979
(in millions of dollars)

Agency	Total	(1) Traditional Small Research Projects (Grant or Contract)	(2) Substantial Research Programs	(3) Research Centers	Large R&D Contracts (4) R&D on Problems Set by the Federal Agency	Large R&D Contracts (5) R&D Conducted in Very Large Facilities	(6) Broad Institutional Support	(7) Other
Total	$3,833[1]	1,815	465	551	492	159	258	95
NIH[2]	1,770	897	210	315	210		52	86[3]
NSF	602	494	42	32		34		
DOD	364	176	73	43	39	33		
HEW (other than NIH)	163	70	25	28	33			7
Energy	292	35	60	70	57	70		
Agriculture	206	15					191	
NASA	144	68	21	19	30	6		
AID	67	3	5	8	51			
EPA	50	3	8	10	29			
Interior	40	3	5	10	12	10		
Commerce	29	5	6	4	7		9	
DOT	19	6			13			
Other[4]	87	40	10	12	11	6	6	1

[1]Source: Special Analysis of the Budget of the U.S. Government, 1981, Special Analysis K. Research and Development, p. 311.
[2]Distribution by type for NIH assumed to be the same as in FY '78, which is the last year for which NIH has analyzed grants and contracts by type.
[3]Research career awards; minority biomedical research support.
[4]Distribution by type of support assumed to be the same as the distribution of all other agencies combined.

Large Facilities

This category refers to organizations which differ from research centers in that they are based on large, special, physical facilities or instruments, such as a high-voltage electron microscope or a nuclear reactor. The sponsoring agency often requires that the facility be made available to investigators from other universities. Contracts are normally used to finance these facilities, with provisions which enable the sponsoring agency to monitor closely the operation and use of the facility.

General Research Support

In this type of funding mechanism a federal agency provides funds to an organization to perform research in some general area or to maintain or strengthen its research capability. At present only two federal agencies provide such general research support, the Department of Agriculture (USDA) and the National Institutes of Health (NIH). The Department of Agriculture provides funds authorized under the Hatch Act for research in agricultural experiment stations. These funds must be matched by state appropriations. The experiment stations are attached to land-grant universities and have a relatively free hand in determining the specific research to be undertaken so long as it is agricultural research.

The National Institutes of Health Biomedical Research Support Program grants funds to eligible institutions for general support of health-related research in the biomedical sciences. The grants are awarded on a graduated formula basis related to the annual total amount of Public Health Service research project grant support awarded to the institution. An entitlement threshold and a ceiling limit the number of recipients and the size of the award. The program currently makes approximately 400 awards ranging from $25,000 to $200,000. Responsibility for allocation of the funds among eligible users is delegated to the grantee.

For a number of years the National Science Foundation (NSF) also awarded institutional grants for science on a formula basis, related to the total federal project research funding awarded to the institution. This program was discontinued in the early 1970s.

In the 1960s, the National Science Foundation provided another type of broad institutional support through a University Science Development Program and a Departmental Science Development Program. These programs were designed to develop "new centers of excellence." The Science Development grants were typically $5 million spread over a few years. The intent was to strengthen a major part of a particular university's science effort, and the grants usually embraced several departments of the institution. The Departmental Science Development Programs, on the other hand, focused on individual departments. Both types of grants were distributed widely around the country and were intended to benefit universities which were in a stage of development where substantial new funds could have maximum impact on the scope and quality of research effort. Universities which already had large, high quality programs and universities believed to be incapable of building significant quality with the funds available were not considered for these awards. These NSF programs also were eliminated in the early 1970s.

The two other types of funding mechanisms which follow are not included in the tabulation of Table I but are important components of federally funded university research.

National Laboratories

A considerable number of national laboratories have been established to perform research and development in major areas of national interest. These typically have their own large professional staffs which perform research, but they also develop and operate facilities which are used by university researchers from all over the nation. These laboratories include the Fermi National Accelerator Laboratory in Batavia, Illinois; the Brookhaven National Laboratory on Long Island; the National Radio Astronomy Observatory with sites at Charlottesville, Virginia, Green Bank, West Virginia, Socorro, New Mexico, and Kitt Peak, Arizona; the National Astronomical Observatory at Kitt Peak, Arizona; the National Center for Atmospheric Research at Boulder, Colorado; and others. These laboratories are usually operated by consortia of universities under contract to a federal agency.

Training Grants and Fellowships

Some federal agencies grant funds to universities or to individuals to support predoctoral or postdoctoral research training. The primary purpose of such grants is to assure the future availability of well trained researchers in general or specific areas where a national need is perceived. However, since individuals can be trained to do research only through actually doing research, training grants and fellowships contribute to the research productivity of the institutions in which the training takes place. Most such training is conducted at universities.

Other Mechanisms

The categories described above are quite broad. Within these categories the federal agencies have developed a versatile array of distinct programs tailored to meet specific needs. For example, NIH has developed the Research Career Development Awards, which provide a period of uninterrupted research time to encourage and strengthen investigators of exceptional promise. NSF has developed doctoral dissertation grants to strengthen the quality of dissertation research in certain fields. NIH, NSF, and DOE (Department of Energy), have developed ways to aggregate closely related research projects into a research program via their "program project grants," "coherent area grants," and "cluster grants," respectively. NIH, NSF, and DOE offer special research initiation programs for new investigators. Many other examples could be cited.

Funding Instruments

In addition to the types of funding mechanisms described above, the various funding instruments used for the support of research also must be considered because the nature of the funding instrument can profoundly affect the performance of the supported activity. The principal instrument types are grants, cooperative agreements, and contracts. Other funding instruments are theoretically possible, such as loans, loan guarantees, and subsidies, but these generally have not been used to support research in universities. Each of the principal types has a number of variations which differ with regard to the basis on which funds are provided, the degree of federal involvement in the definition and technical performance of the supported activity, and the specificity of the purpose of the contractual relationship. For example, the funds may be provided on a cost reimbursement,

grant-in-aid, or formula basis and involve various degrees of cost participation by the recipient. The degree of federal involvement may be minimal; it may involve shared direction and control; or it may involve federal oversight.

The federal procurement system for acquisition of goods and services for the benefit and use of the Federal government has evolved over many years. A comprehensive set of procurement principles and procedures has been developed, tested, and revised. A substantial body of procurement case law exists. Federal assistance programs, however, are a much more recent addition. No comprehensive system exists for their guidance and management. Nor has there been, until recently, any clear guidance regarding the appropriate choice of funding instrument for a given purpose. The result has been confusion in terminology and concepts, inconsistent practices, mismatch in expectations of performer and sponsor, and misunderstanding, especially regarding the nature and purpose of grants. Because the boundary between procurement and assistance has not been well understood, procurement-based requirements have frequently been used in assistance situations.

In 1972, the Government Procurement Commission recognized these problems and recommended that a study be undertaken to examine the feasibility of establishing a comprehensive system of guidance for management of federal assistance programs. The Federal Grant and Cooperative Agreement Act of 1977 (Public Law 95-224) codified that recommendation and mandated a study which has been completed just recently. In the intervening years, federal assistance programs have increased manyfold, primarily in assistance to state and local governments. Federal assistance activities are now carried out through more than 1,100 programs with an annual budget of over $100 billion, more than 85 percent of which is awarded to state and local governments.

The Federal Grant and Cooperative Agreement Act established two dichotomies: first, between assistance and procurement; and second, to divide assistance based on the involvement of the government in performance of the activity. The Act then mandated the use of contracts for procurement, grants for assistance without substantial involvement of the government, and cooperative agreements for relationships where the government is substantially involved.

Strengths and Weaknesses of the System

Funding Mechanisms

The objective assessment of the strengths and weaknesses of the system of mechanisms through which the Federal government supports university research is a difficult task. The difficulty is rooted in fundamental differences in objectives, functions, and philosophy between the government and the universities, and in the great diversity of agencies and institutions on both sides of the partnership.

The Federal government has for nearly two centuries rather consistently taken the position that it should support research only where the results of that research can be expected to satisfy a clearly identifiable national need. Jefferson's Congress was willing to support exploration "for the purpose of extending the external commerce of the United States" but not as a mere "literary pursuit." The Federal government long avoided any substantial involvement in education; George Washington's personal offer of an endowment for the establishment of a national university which would, *inter alia*, provide advanced scientific training, was rejected by Congress despite support by Jefferson and Madison. Support of learning for its own sake or of intellectual institutions as centers of national culture have never been popular notions in Washington. The tensions between the Federal government and the states, between elitism and populism, and between the theoretical and the practical, which have molded so much of the American character, have also strongly influenced the government-university research endeavor. The government funds research in support of its responsibilities for the security and welfare of the nation. Most federal agencies which support research have specific missions addressing one or more aspects of the government's responsibilities. In the cases of the National Science Foundation, the National Endowment for the Humanities (NEH), and the National Endowment for the Arts (NEA), the federal agencies' responsibilities are more broadly and generally defined than Jefferson's Congress might have found to his liking.

The extraordinarily fruitful collaboration between university scientists and the government during World War II led to the recognition of the potential of such cooperation for the public welfare. Our nation has also come to recognize both the importance of long-term investment in basic research and the relationship of scholarship and the arts to the intellectual and moral fiber of our people. Nevertheless, the fundamental interest in tangible results which promote the national welfare is never far below the surface.

Because of this basic federal philosophy, the federal agencies which support research tend to seek certain characteristics in funding mechanisms. There is a desire for control, equity, and consistency. There is a natural

predilection for the more applied, the more predictable, and the lower risk research. In some cases, these desires lead agencies to treat expenditure of funds for research in the same way as expenditure of funds for the procurement of pencils or ships. In all cases, the need for proper accountability to the citizenry, in matters both scientific and financial, imposes constraints which an acceptable funding mechanism must satisfy.

The research universities operate from a different tradition and philosophy. Research and scholarship are commonly viewed as important ends in themselves, worthy of support, together with the institutions which nurture them, as a general public good without consideration of immediate practical usefulness. In matters of research and scholarship, the best is so incomparably better than the second best that universities put great emphasis on quality. Creativity is so highly valued that universities vest their researchers and scholars with considerable independence and freedom in choosing what research they will do and how they will do it. The universities' monastic origins and their modern status as non-profit, private institutions or as public wards of a state place most of them in delicate financial positions, subject to the fluctuating fortunes of a host of different patrons and clienteles.

The research universities thus often seek different funding mechanism characteristics than do the federal agencies. Flexibility to exploit scientific opportunities is important. Emphasis on scientific merit may lead to concentration of the available resources in the hands of a few outstanding researchers rather than spreading them widely among many. There is a tendency to regard most highly the more fundamental research and work with higher risk and higher scientific payoff. Where a university has come to depend heavily on federal support for its research effort, as most major research universities have, stability of support over time is important. Although most research universities invest substantial amounts of their own resources in support of research, the magnitude of these research efforts creates the need to maximize recovery of research costs from federal sponsors. The maintenance of close links between research and teaching, and the minimization of administrative burden are also important university objectives.

These differences between the objectives and perceptions of government agencies and the research universities mean that a particular feature of a funding mechanism may be a strength to an agency and a weakness to a university, or *vice versa*. As this report discusses the funding mechanisms defined above, it endeavors to describe them from both points of view.

Individual Research Projects

The backbone of the American science system which is conducted in universities is the individual project grant or contract, with almost half the entire federal support for academic science provided through this mechanism (cf. Table I).

There are many advantages to the individual project scheme. It gives an opportunity for a large number of investigators to seek federal funds on a competitive basis. The most worthy proposals, judged in a peer review system where the most informed scientific judgment can be brought to bear, can be selected for support. The relatively modest funding level typical of individual project grants or contracts permits support of a large number of individual investigators; this mechanism thus can distribute support relatively widely. The mechanism also provides an opportunity for many different agencies to support programs of interest to them. By supporting a large number of relatively small projects, federal agencies can have the flexibility to shift emphasis in research programs without disrupting large research enterprises. For a large research university, as many as 1,000 to 2,000 such projects is not uncommon. In these circumstances, fluctuations in total institutional funding will tend to be relatively small, therefore providing the appearance of stability. However, funding fluctuations at the level of individual investigators can be large.

On the other hand, the project system is a "retail" system, requiring decisions on tens of thousands of relatively small grants per year, and therefore involves a large amount of administrative detail for both the government and the universities. Each grant constitutes a separate agreement between a sponsor and a performer. Each requires individual review as well as scientific and financial accounting and reporting. This tends to segregate funds and scientific effort in small, impermeable compartments and creates a certain amount of rigidity and inflexibility. The system shifts to universities and academic departments the burdens of providing the resources required for the common support of many investigators, for coping with awkward gaps in research support, for supporting individuals and their research during periods when they have little or no external support, for helping younger investigators get started in research, for developing and maintaining research capacity, and for maintaining a proper balance among fields. These burdens are a necessary byproduct of the individual projects system, but institutional and external resources for addressing these needs have been sharply curtailed in recent years.

Research Programs

Although we have distinguished research programs from individual research projects in order to present a complete picture of the array of funding mechanisms, the strengths and weaknesses of the two mechanisms are similar. The larger size of research programs relative to individual research projects can reduce administrative burden for federal agencies, researchers, and their institutions. It can also increase the researchers' flexibility but may decrease funding stability in the institution.

Research Centers

Academic research, particularly in the sciences, encompasses much more than the basic research performed by individual investigators. Most major national research universities perform both basic and applied research, some of it requiring large and expensive physical facilities. Some of this work is carried on within academic departments, and agencies make large grants to departments, or to groups within departments, on a "wholesale" basis. In these cases, the departments or groups are responsible for the "retail" funding allocation decisions necessary in the execution of the research projects. DOE- and NSF-funded high energy physics and nuclear physics groups within university physics departments provide examples of this funding mechanism. In such cases, the peer review process includes a significant intra-department or intra-group element, and questions can arise about its breadth and objectivity. With competition for federal funds decided at the local level, intra-departmental relations may be strained.

The federal objective often involves research programs for which an academic department is not the best form of organization for pursuit of the research. To provide appropriate organizational arrangements in these cases, nearly every major research university has an array of research institutes, laboratories, or centers designed to bring multidisciplinary and interdisciplinary skills to bear on such research. These centers, whether based on a single discipline or several disciplines, can provide common services for a large number of investigators. Where center funding sources permit, a center can provide flexibility for individual investigators to change direction quickly when new research opportunities arise, as well as initial funding for young investigators and for mature investigators who wish to enter a new area of research.

University organizations for the performance of large scale research usually include a director who may be full or part time, and they usually provide for local policy guidance by a policy or administrative board. The organization generally provides for internal peer review as a part of the local funding allocation process. Federal oversight is commonly exercised through prior agreement with the institution about research focus, through external peer review of center proposals, and through periodic site visits by agency officials and external peer reviewers.

From the standpoint of the federal agencies, centers or similar, organized research units are an effective way of mobilizing universities for research work on problems of significance to the agency. However, there can be difficulties between the sponsoring agency and the university if the mission of the center is not clearly stated and mutually understood. Centers tie up large amounts of agency funds for long periods. While this is advantageous from the research support stability standpoint, it decreases the flexibility of the federal agency and limits the number of new directions the agency can undertake.

From the standpoint of the universities, centers offer a means of mobilizing resources more effectively than is possible within academic departments. Departments bear the responsibility for the curricular and teaching functions of the institution and provide the foundation for the system of faculty appointments and tenure. This gives the departments permanence but also a degree of rigidity. On the other hand, a proliferation of centers can blur the authority of administration in the universities.

Also from the standpoint of the university, major problems are apt to be generated when funds are withdrawn. The termination after Fiscal Year 1971 of the university centers funded for a decade by the National Aeronautics and Space Administration (NASA) in its Sustaining University Program is a case in point. The problem becomes particularly acute if tenured faculty members are supported on center funds. Many universities have elected to keep tenured faculty members on "hard" university money, and some universities have even established reserve funds in anticipation of possible withdrawal of federal funds.

The central research support services which the university has built up through the use of indirect cost reimbursements to meet the needs of a center are apt to represent a burden if the center is closed. Such services can rarely be dismantled or reduced as rapidly as the center's external support can be phased out.

The prospect of large scale support has sometimes led universities to accept support for a center without full

consideration for the administrative responsibilities and complexities involved. Substantial financial risk is accepted when a grant or contract for a large center is accepted. Such agreements normally include termination clauses, usually providing for termination at the convenience of the government, with provision for reimbursement only of immediate termination costs.

While many university centers are supported through a combination of relatively small project and program grants, a number of federal agencies support large research efforts in specified areas at particular universities with block grants. These are grants which may include annual support of up to several million dollars awarded to the university, with the detailed administration of the grant delegated to the institution. Research programs supported with such grants include the National Science Foundation Materials Research Laboratories, created and originally funded by the Advanced Research Projects Agency of the Department of Defense (DOD); the National Institutes of Health Categorical Disease Centers; various large high-energy and nuclear physics research programs, some supported by the Department of Energy and some by the National Science Foundation; and the Department of Interior's Water Resource Research Centers.

The materials sciences provide a rare opportunity to assess the relative advantages and disadvantages of block-funded research centers and individual research project funding, because in this research area both mechanisms are used to a substantial extent. In 1978, the MITRE Corporation completed a massive comparative study of materials research conducted in the National Science Foundation's core-funded Materials Research Laboratories (MRLs) and materials research supported by project grants in other institutions. In the latter group, some institutions had separately organized Materials Science Centers and some did not. Also included were several interdisciplinary laboratories (IDLs) supported by the Department of Energy. The major conclusions of this study were:

- Universities with MRLs have a better capability (in terms of faculty and equipment) to perform materials research than non-MRL universities without Materials Science Centers. The capability of non-MRL universities with Materials Science Centers is much like the MRLs.
- From the viewpoint of total (university and NSF) administrative time and costs involved in administering grants, the MRL core grant mechanism is much more efficient than the project grant mode.
- About 70 percent of the materials research areas sponsored by NSF at the institutions surveyed show no overlap between MRLs and project-funded institutions.
- Research at the MRLs is more heavily oriented toward experimentation than research at non-MRLs without Materials Science Centers.
- There are no significant differences between MRLs and non-MRLs in concentration of funding, annual rate of turnover in research areas, duration of research areas, and continuity of staffing.
- The review of research publications does not show a clearcut dominance of one population over the others being compared. There is no statistically significant difference at the 90 percent confidence level among any of the populations with respect to interdisciplinarity and overall indicators of innovation. In quality of procedures, the NSF core-funded papers rank higher than project-funded ones. In contributions per paper to research or technology NSF core-funded papers rank lower than project-funded. In the use of essential specialized equipment, excluding computers, core-funded papers rank higher than papers from non-MRLs with Materials Science Centers but lower than papers from DOE/IDLs.
- Citation analysis shows that only NSF/Project-funded papers at MRLs were cited with significantly greater frequency than MRL core-funded papers. The latter were cited with about the same frequency as papers from DOE/IDLs and NSF/non-MRLs without Materials Science Centers.
- In major achievements, the MRLs have much more than a proportional share (based on total NSF funding) rated in the top 15 percent. However, the MRLs have slightly less than a proportional share of achievements rated in the top 25 percent.[2]

These conclusions do not demonstrate a clear superiority for one funding mechanism over the other. They do suggest that different funding mechanisms give rise to different ways of doing research and produce different kinds of science, and thus increase the diversity of the national research effort and expand the range of new knowledge available for application.

Research on Problems Set by a Federal Agency

When a federal agency identifies a problem requiring research, it usually can choose from among a variety of possible types of performer. It may have its own in-house laboratories, or it may consider contracting with a government laboratory belonging to another agency, an industrial laboratory, a federally funded research and development center (FFRDC), a university, or another non-profit research organization. A university may be the performer of choice because it may have special expertise or facilities, because it may offer lower cost, or because secondary benefits such as the training of researchers in a new area may also be valued. On the other hand, a university may be an unattractive choice because its commitment to teaching as well as research and its decentralized structure may make difficult mobilization of its resources within the desired time span.

From the university's point of view, the conditions which accompany an opportunity to work on a strongly focused government project may not be compatible with certain university principles and commitments. For example, the government may seek an unacceptable degree of control over the direction of a project or attempt to impose unacceptable restrictions on publication of results or on personnel matters. In such cases, the university's desire to be of public service must be weighed against the danger of compromising the basic institutional functions of instruction and research. The university's decision to become involved in research programs of this type will depend on the nature of the institution. It will generally be made on a case by case basis with due regard to the overall balance of the institution's research effort and the availability of faculty interested in the particular problem.

Large Facilities

From the government point of view, the establishment of a specialized research facility at a university may have several advantages: it places the facility within a community of skilled users, the environment may be made readily accessible to other users, and there are the collateral benefits of training in advanced techniques for research students. These same factors make the facility attractive to the university. However, the university may find it difficult to provide the managerial capacity required for a large facility and may be unprepared or unable to cover hidden costs which such facilities often entail. Again, some institutions will be better suited to house large facilities than others, and both the sponsoring agency and the university need to be fully alert to all the implications before entering into large facility agreements.

General Research Support

To a federal agency struggling to stretch limited funds over the largest possible range of high quality research, the option of providing funds for general support of research activities of a research organization is often unattractive or at least of low priority. From the agency's perspective, the use of this type of funding mechanism dilutes the agency's direct control over the use of its funds. It raises both concerns about quality assurance and fears that funds may be diverted to non-research purposes. On the other hand, decentralization of some allocation decisions is advantageous for the agency since it can reduce delays and administrative costs and increase the productivity of the funding system.

The universities see general research support as an important element of a balanced research funding system because it allows prompt and cost effective responses to the gaps inherent in the individual research project funding system. Emergencies, unexpected opportunities, new starts, and development of shared resources are typical funding needs which are inadequately addressed by the project system.

Individual investigators have mixed feelings about general research support. While they recognize the importance of the needs it addresses, they fear expansion of general research support at the expense of project support. Their primary concerns are quality assurance and preservation of the relative independence which their relationships with external sponsors provide.

Where local or regional needs and conditions are a key factor in determining what research should be done and how, as in agricultural research, general research support rather than centralized federal project support offers advantages.

National Laboratories

While the national laboratories are not university laboratories in a strict sense, they have a major impact on academic research. The large facilities represented by the national laboratories are usually operated as national

facilities through consortia of universities for the benefit of academic research scientists. They are essential features of the scientific research enterprise of the nation. These laboratories provide large and expensive facilities, usually not easily accommodated at universities but vital for research in the fields they represent.

The relative allocation of funds between the national laboratories and university researchers is a frequent matter for debate. In astronomy, for example, approximately three-quarters of the National Science Foundation budget for support of research in astronomy goes to the five national centers or observatories: the National Astronomy and Ionosphere Center (Arecibo), the National Astronomy Observatory at Kitt Peak, the Cerro Tololo Inter-American Observatory, the National Radio Astronomy Observatory, and the Sacramento Peak Observatory. These funds support the operations at the observatories, which are used both by their own research staff members and by university researchers. While few would challenge the essential nature of these large laboratories, there are those who challenge two aspects of their operations. These are, first, the distribution in funds between the national laboratories and individual user projects and, second, a system which is sometimes perceived to afford research support opportunities to the national laboratory permanent staff without the stringent peer review evaluation required for proposals by individual project scientists. As with other aspects of the national research funding system, this is a question of seeking the best balance of characteristics among those available in the competing mechanisms.

Training Grants and Fellowships

Training grants and fellowships have generally been viewed by the Federal government as a means of encouraging the creation of a future supply of investigators rather than as a component of support for current research productivity. Consequently, the level of funding has undergone large fluctuations as perceptions of future manpower needs have changed. Shortly after the launch of Sputnik, the number of federally funded fellowships for scientists increased dramatically. An equally dramatic decrease occurred about a decade later; for example, the total number of fellowships and traineeships in physics went from over 2,700 in 1968 to fewer than 900 in 1975. The number of young investigators produced by our universities has not varied so rapidly nor so greatly as the number of fellowships and traineeships, partly because of the time lag associated with the long time required for development of a college freshman into a fledgling scientist and also because many students find other means of support such as part-time jobs, teaching assistantships, and research assistantships funded through individual research grants. Nevertheless, these large fluctuations in federally funded training grants and fellowships have contributed to instabilities in federally funded university research programs. Variations in graduate student support will continue to be of concern to both the government and the universities in the future. The difficulties of predicting manpower supply and demand and the complex and long delayed effects of any attempt to drive the system through changes in funding for training make this funding mechanism one to be manipulated only with great caution.

Funding Instruments

The assessment of the advantages and disadvantages of the use of grants, cooperative agreements, and contracts as the funding instruments for federally sponsored research in universities is sorely complicated by the variation among funding instruments carrying the same name. For example, an Office of Naval Research (ONR) contract for the support of basic research provides more flexible operation than certain grant arrangements with agencies which have predominantly "assistance" relationships. The dichotomies established by the Federal Grant and Cooperative Agreement Act, between procurement and assistance and between grants and cooperative agreements, yield an array which is neither benign nor malevolent to research. The clarity sought by the grant/contract dichotomy is too elusive to be reached only by the enactment of Public Law 95-224. The practices of agencies and the attitudes of their personnel are the principal administrative determinants of the ability of the awardee to carry out research effectively. Many researchers have made the point in testimony before the Commission that the characteristics and administration of an award (contract) from the Department of Defense are more like assistance than an award (grant) from the Department of Energy.

The attitudes of researchers and university administrators are also a significant factor. Both researchers and university administrators have been influenced by their experience with some agencies' practices in the use of these instruments. Biomedical research, for example, was long supported by NIH via grants. In the early 1970s, that agency markedly increased its use of the contract, a move that caused serious concern in the academic research community. The root of this concern lay primarily in the accompanying shift from researchers to the

agencies of the locus of responsibility for deciding which problems were ripe for study, and in the selection of contractors without rigorous peer review. There was also concern about federal involvement in performance of the work and increases in administrative requirements. The NIH move to increased use of the contract mechanism was influenced by the plans for a war on cancer and heart disease and by an increased administrative emphasis on employment of management principles in all facets of federal activity. Much of the biomedical research community questioned the expectations that difficult scientific problems could be solved simply through application of money and management. In their view, this area of research was primarily in need of good ideas which could not be "managed" into existence. Many in the biomedical research community continue to resist or distrust the use of the contract as a result of this experience. The pendulum has recently swung back; NIH now makes much less use of the contract as a funding instrument.

Some contracts, such as those awarded by ONR for basic research, have been flexible enough to nurture exploratory work. Some grants, such as those awarded by the Office of Education and the National Endowment for Humanities, have provided little or no flexibility, especially with regard to internal budget changes during the award period. Some agencies, such as DOE, require in both contracts and grants frequent and burdensome technical and managerial reporting which may be appropriate for demonstration or development work, but which is unnecessary and unproductive for basic research.

Problems in the Current System of Funding Mechanisms

The establishment of the National Commission on Research was motivated by a growing perception among thoughtful observers of the American research enterprise that strains have developed in the government-university research partnership which seriously threaten its vitality. These strains have been discussed and documented by many authors, e.g., B. L. R. Smith and J. J. Karlesky in *The State of Academic Science—The Universities in the Nation's Research Effort*. The Commission has not undertaken extensive independent studies of its own, but has reviewed existing work such as the Smith-Karlesky report, and has interviewed numerous federal officials and university administrators and researchers. A partial listing of these individuals appears in Appendix II. A part of the picture which has emerged from our efforts concerns funding mechanisms. In general, the current system of funding mechanisms is viewed as basically sound and possessed of substantial strength derived from its diversity and flexibility. Nevertheless, close inspection reveals a variety of problems which call for attention from all the participants in the system. The system is not working as well as it could and should.

The shift from rapid expansion of research support through the 1950s and 1960s to the current state of tightly limited resources has necessitated changes throughout the government-university research enterprise and, in particular, this has brought questions of balance among types of research, sponsor, performer, and funding mechanism into sharp focus. Competition among fields of research, among institutional performers, and among individual researchers has become severe. Margins for flexibility and risk taking have dwindled and vanished. New initiatives can be considered only at the expense of continuing programs. Although none of these difficulties are unique to the research enterprise, their effects may be particularly damaging there because research cannot thrive in an atmosphere of stasis and conservatism. In considering specific problems in the funding mechanism system, we must keep in mind that their solution through substantially increased funding in real dollar terms is not likely. Instead, we must look for improvements which can be made within a generally constant funding environment.

The Commission has identified the following specific difficulties.

Difficulties in the Array of Funding Mechanisms

While the array of funding mechanisms includes a remarkable diversity of program types, some elements are missing. The missing elements are illustrated by three types of problems.

A Rapidly Developing Equipment Inadequacy Problem

American science is currently suffering from inadequate and obsolete equipment. Several factors contribute to this situation. First, development of new types of equipment has been unusually rapid in recent years because of the rapid development of measurement and instrumentation techniques. These developments are based in part on rapidly developing computer technology and on the maturation of other equipment technologies based on earlier scientific developments. The availability of entirely new types of equipment opens new opportunities to pursue the unknown, opportunities which cannot be exploited without the equipment. In many fields the ability to work at the frontiers depends entirely on access to the necessary equipment.

Following is an illustrative example: one of the byproducts of nuclear weapons development during and after World War II was the copious production of a variety of radioisotopes. The use of these radioisotopes as tracers in chemical and biomedical research has become a standard tool and has contributed enormously to advances in these fields. The equipment required to use this technique created a significant increase in instrumentation complexity and sophistication in these fields, but was nevertheless on a scale which could be afforded and used by individual investigators. The technique is not without disadvantages, not the least of which is the problem of disposal of radioactive experimental materials.

Another technique discovered shortly after World War II is nuclear magnetic resonance. Although it was developed and first used in physics, it too has become a standard tool in chemical and biomedical research. As a consequence of a long series of advances in electronic and computer technology and in such seemingly unrelated fields as superconductivity, nuclear magnetic resonance technology has now developed to the point where isotopic species can be identified and the amount of a particular species present in a sample measured with high sensitivity and accuracy. These developments now make it possible to use stable but rare isotopes as tracers in

chemical or biomedical experimentation. This eliminates the requirement for radioactive tracers and the radioactive waste disposal problems which accompany their use. But there is a significant drawback: the equipment required costs on the order of a half million dollars and requires skilled operators and sophisticated maintenance.

This example illustrates three common characteristics of evolving instrumentation technology: the opening of new opportunities, the trend toward greater complexity and cost, and the presence of trade-offs among advantages and disadvantages.

A second factor contributing to the present serious equipment situation is a combined effect of the constant or decreasing total research funding of the past decade, coupled with increasing numbers of qualified researchers generated by the post-Sputnik drive to produce more scientific manpower. Hopes that the funding crunch will abate some day soon lead researchers repeatedly to defer capital acquisitions in favor of sustaining research personnel.

The origins of the "equipment crisis," as some term it, are many and complex, and solutions to the problem will not be found exclusively in improvements in funding mechanisms. Still, the structure of the current system of funding mechanisms has contributed to the problem. The typical funding level of an individual research project does not accommodate acquisition of any but the most modest types of equipment. Requests for substantial items of equipment in a proposal for such a project are often the first element deleted in the inevitable paring of a requested budget to an awarded budget. Such deletions usually are favored by both agency program officers and by the peer reviewers on whose advice they rely. To a considerable extent, both groups are strongly influenced by the desire to provide at least partial personnel and operating support to all the investigators whose work receives high scientific merit ratings. This favoring of people over equipment is intended to preserve the vitality of new ideas and to ensure continuity in training the next generation of research scientists.

The compartmentalization of individual research projects makes difficult the pooling of funds from different projects or by several individual investigators to purchase equipment for shared use. In some cases, sharing is further inhibited by the inability of institutions to remodel and renovate space in which to co-locate research groups to facilitate equipment sharing. It should be noted that a recent national survey[3] of shared use of scientific equipment at colleges and universities revealed that more than 45 percent have either already established systems to facilitate equipment sharing or plan to do so in the near future.

Although NSF has programs in which funds are segregated specifically for equipment grants, these are sometimes criticized by the research community because funds so identified are viewed as taken from sources otherwise available for support of conventional individual research projects.

Where funds are made available for major instrumentation for shared use within an institution or on a regional or national basis, other problems arise. Rarely do either the government or the institutional grantee adequately project and provide for the costs of housing, maintaining, and operating major equipment acquisitions. Over the lifetime of a major instrument, such costs can easily exceed by many times the capital cost of the instrument.

Neither government agencies nor research universities now have policies and mechanisms for coping with the general, long-term need to maintain the national research equipment inventory against the inevitable inroads of obsolescence.

The "equipment problem" has been the subject of repeated studies and comments.[4] Additional studies are in progress. The relative reduction in investment in equipment by funding agencies and its impact on institutions have been reported. For example, a typical midwestern public research university reports that the ratio of equipment expenditures from federal research funds to total federal research fund expenditures dropped from 14 percent in 1963 to 10 percent in 1973 and 5 percent in 1978. During the same period, inflation and increased complexity of research problems to be solved severely taxed resources for equipment. An NSF survey[5] recently showed that the cost of scientific instruments in five basic science areas has increased fourfold since 1970. The investment required to equip new investigators is becoming a major problem. The universities' own resources have become too limited to provide what is needed. "Young investigator" grants usually assume availability of major equipment, and hence often seek an end without providing the necessary means. Furthermore, many highly sophisticated instruments require technical personnel to operate the equipment or supervise its operation and maintenance. Present mechanisms for distributing costs of such personnel are inadequate. They frequently depend on prior involvement and an overall commitment which fewer and fewer institutions will be able to make. This is a serious flaw in the short-term and discrete project system of financing basic research.

The problem is escalating in severity. A steady state system is needed in which replacement of worn out and obsolete equipment is structured into consideration of project costs.

Inadequate Provision for New Research Initiatives and for Sustaining Research Capacity

Current heavy reliance on individual research project funding creates gaps in the research support system. Universities are increasingly unable to fill these gaps. Cost effectiveness often dictates shared use of research facilities, and such facilities are often too large to be supported by any single project. It becomes the university's problem to provide such facilities, but the institution has little or no means other than *post facto* indirect cost recovery over a period of years. Frequently, unexpected needs or opportunities arise in ongoing investigations with no available funds to meet these needs. There may be a hiatus between grants where only institutional funds can bridge the gap. Young investigators need initial support to establish a performance record so that they can compete effectively in national competition. Established scientists occasionally change the direction of their research and need temporary support while they develop credibility in the new field. From time to time, new research areas emerge and appear promising, but until exploratory work can be accomplished there is no adequate basis for a proposal for project support. At present, institutional funds are likely to be the only source of support for such exploratory work or for any of the research capacity needs described above.

Research universities acknowledge that they have a responsibility to maintain an environment conducive to the research of their faculty. They devote substantial resources to this end in addition to the research support received from the Federal government. However, the sheer magnitude of the federally sponsored research effort at the major research universities, together with increasingly stringent restrictions on funds from other sources such as tuition and state appropriations, has put most universities in a position where they can no longer maintain an adequate research infrastructure without additional aid.

The present array of funding mechanisms provides inadequately for venture capital and research capacity maintenance. Institutional resources alone cannot meet the need. Deterioration of the productivity of the research enterprise may well be inevitable if the problem is not addressed. The NIH Biomedical Research Support Grant Program is one successful example which might be extended to other fields of research.

Erosion of Institutional Support for Research in the Humanities and Social Sciences

Traditionally, much of university research in the humanities and social sciences has been in basic research and of relatively small scale. The primary resources needed are often simply time for research, access to libraries and data sets, clerical support, research assistance, and publication support. Such research makes an important contribution to national life and to world understanding, but the magnitude of the needs of individual projects makes a highly centralized individual project support system, like the one which is used in supporting science and engineering research, cumbersome, inefficient, and costly.

At present this research is supported primarily by universities and private sponsors such as the foundations and to a limited extent the Social Science Research Council (SSRC) and the American Council of Learned Societies (ACLS). Some federal support is provided to SSRC and ACLS, but these organizations rely primarily on the foundations for support. Federal support is directed almost exclusively to large-scale projects and development of research materials and research resources, although a modest fellowship support program is available for research in the humanities. Several universities have established successful institution-based award programs for small-scale research. Some of these are targeted exclusively for the humanities.

Although the federal support of social science research as a fraction of total federal research and development support has remained essentially constant for a number of years, this support is not directed to small-scale research. Furthermore, a recent NSF review of this situation revealed a noticeable change in the distribution of federal social science research support among types of performer. Researchers in universities have received less of the support in recent years, while independent consulting organizations have received more. The character of the social science research undertaken with federal support also has changed, with a significant fraction now being highly targeted to address specific agency policy questions. These changes, therefore, increase the demand on universities and private sponsors for more general social science research support.

The present resources for small scale research in humanities and social sciences are quite limited. If adjustments are not made, the outlook for the future appears worrisome. Within universities, enrollment shifts away from the humanities and social sciences disciplines create pressures for resource reallocation to meet enrollment

increases elsewhere. Economic pressures are severely taxing institutional capacity to maintain discretionary programs. Shifting federal support from the social sciences makes social science investigators in universities more dependent on institutional resources. Unmet research capacity maintenance problems combined with cost-sharing requirements in the system for support of research in sciences and engineering have become a serious drain on institutional resources and compete with institutional needs for supporting research in the social sciences and humanities.

The universities, the private sponsors, and the government will need to attend to these emerging problems.

Difficulties in the Funding Instruments

The funding instrument difficulties the Commission identified are of two types: difficulties with certain terms of the agreements and difficulties related to the underlying relationship between sponsor and performer.

Continuity and Stability

Continuity and stability are often missing. One of the most commonly perceived weaknesses in the present system is the lack of continuity. For maximum effectiveness, research projects must operate for a period long enough for serious accomplishment. Effectiveness can be impaired seriously if research is forced into short-term planning and funding cycles. In many basic research fields, annual or biannual renewal cycles are simply too short to permit acquisition of equipment and supplies, staffing for the research activity, and implementing the research strategy. Longer periods of assured support are vital. The National Science Foundation and the National Institutes of Health have been moving in the direction of better continuity by using grant periods which average two to three years. However, some agencies continue with one year support. Much of the time devoted to development and review of frequent renewal proposals is time diverted from performance of research. Where it is possible to design longer support into the system, the cost effectiveness of the whole enterprise can be improved.

Part of the continuity problem is associated with delays in renewal of support for ongoing programs. Such delays create funding gaps. When this occurs, either work must cease or support must be transferred from some other source. Universities commonly look to internal sources to underwrite the project temporarily, if eventual renewal of the project seems assured. At best, this leads to the burdensome paperwork of cost transfers to the renewed contract; at worst, it leads to non-reimbursement of costs incurred in the funding gap if the contract is not renewed or if it fails to include the gap within the new contract period or to authorize pre-award costs. On the other hand, if work were stopped and personnel dismissed when funding gaps occur, research progress would be significantly disrupted and delayed. It should also be noted that cost transfers associated with funding gaps are frequently at the root of accountability problems in the administration of research funds.

While some agencies are able to avoid funding gaps, many issue the formal notification of award only days before the effective date of the support agreement. This forces the research institutions to unfair and needlessly disruptive practices. Research personnel must be given more stability than such practices allow.

Surely improvements in continuity and stability are in order. Several mechanisms have been used in the past to provide such continuity and stability. These include: forward funding, roll forward funding, and step funding. Each is discussed below.

Forward Funding

The most straightforward continuity mechanism is multi-year forward funding. The original DOD Interdisciplinary Laboratory contracts in the early 1960s provided four-year funding. This had the advantage of assuring support long enough to acquire the personnel and the facilities to put the research project on a sound base. It had the disadvantage of removing flexibility from the funding agency for an extended period. Even two-year funding puts the research project on a base which is much more sound and likely to make possible much more progress than is the case with single-year funding.

Roll Forward Funding

In this mechanism full funding is guaranteed for a period of two or more years. On the basis of a favorable annual review, an additional year's funding is added to the end of the overall contractual period. In this way, the decision to extend support is always made at least one year in advance. This provides the principal investigator or the university an opportunity to plan ahead with assured funding for a long enough period to make effective

management possible. The mechanism gives the sponsoring agency the ability to terminate projects in an orderly manner with ample warning to investigators and the institution.

Step Funding

Step funding is a version of roll forward funding which provides more flexibility for the sponsoring agency. Where this mechanism has been used it has typically provided full funding for one or more years, followed by two-thirds funding for the next year and one-third funding for the next following year. Each year the pattern is rolled forward one year maintaining the step feature. From the standpoint of the investigator or the university, a degree of funding for a substantial period ahead is assured. From the sponsoring agency's standpoint, continuity can be assured for three years, with the commitment of only two years' funds. If the sponsoring agency elects to terminate the project, the investigator and the institution have an extended period to terminate the work in an orderly fashion.

Flexibility

Flexibility is frequently inhibited. Unforeseen events often occur in research; new opportunities frequently develop in the middle of a research program. When such opportunities arise, it can be in the best interest of all parties to change direction in order to pursue the new lead. In basic research, the flexibility to alter direction is vital. In applied research and in development, research direction is usually somewhat easier to predict. In these latter areas, flexibility is still important, but is not as major an issue.

For the most effective research performance, such research changes must be accommodated with minimum delay and minimum friction between the project director, the sponsoring agency, and the institution. Some changes involve a renegotiation of the scope of work; others simply involve internal budget realignments. A number of persons in both the government and the universities believe that greater flexibility in the procedures on both sides is needed to facilitate such changes. While this is not entirely a problem of the funding instruments, some improvements in funding instruments may provide greater flexibility.

Another area in the post-award administration of sponsored agreements which needs improved flexibility involves cost transfers between related agreements. The compartmentalization of research support into multiple, discrete projects of limited duration may be advantageous for the selection of what research and which investigators to support. But it sorely complicates management of research funds, institutional planning, and research facility development. Cost transfers are an unavoidable consequence of the current system. The research program of a single investigator or group of investigators may be funded by several individual research support agreements, so that specific costs may be legitimately assigned to one or more individual accounts. Prudent management may require some retroactive reassignment of such charges. Agency program officials often are quite aware of the situation and recognize the validity of such adjustments among grants for related research. The present post-award administration procedures, however, make such adjustment burdensome in paperwork and require careful justification to avoid disallowance by auditors who tend to view all cost transfers as suspect.

Not all cost transfers are proper. Care must be taken to distinguish those which are legitimate and represent wise, intended use of public funds from those which are opportunistic. The critical element is a clear understanding about the scope of the intended purpose. If the purpose is defined too narrowly, the research productivity of the nation can be unnecessarily impeded. If it is defined too loosely, federal funds may be used for other than their intended purpose.

The problem of cost transfers to cope with funding gaps has already been described in the discussion of continuity and stability. Creative solutions to these problems which both fit the research process and assure appropriate use of federal funds will enhance research productivity and reduce the potential for actions which create negative audit findings.

Procurement Procedures

Procurement procedures are inappropriately used in research support. There is a widespread belief among university investigators and university research administrators that procedures and attitudes appropriate for procurement contracts are beginning to dominate sponsored agreements for basic research. They see clauses from federal procurement regulations designed for industry entering increasingly into agreements with universities. Even though clauses designed specifically for universities have been developed, industrial-type default clauses, stop work clauses, security specifications, and procurement-style reporting requirements are increasingly used in research agreements in what are perceived to be inappropriate ways. University scientists and admin-

istrators tend to believe that while contract administration in the various agencies was formerly done by scientists, now procurement specialists, trained in the procurement of deliverable products, are administering research contracts. The problem is seen as a particularly serious one in the case of solicited proposals where the Request for Bid provides all the contract language, and if the university raises an objection to the proposed terms, the bid may be viewed as nonresponsive.

On the agency side, the impetus to write tighter contracts appears to be a response to recent allegations of fraud, error, and abuse in university research operations. Undoubtedly, it is also an agency response to limited resources and perceived congressional and public pressure for agency responsibility.

The universities' concern is that the industrial model of tightly drawn advance specifications is gradually being imposed on an undertaking which can only realistically and successfully be pursued on a best effort basis. Much of the federally sponsored research in universities simply does not need and cannot thrive with the hard edge of the procurement policies and procedures.

The universities, of course, do not have to accept contracts which they view as unduly restrictive. The procurement regulations specify a required core of clauses. To a certain extent contract clauses are negotiable, but the university risks losing the prospective research support completely if the negotiation is pursued too vigorously. At best, such negotiation on a contract by contract basis takes time and requires personnel, which increases administrative costs and impedes the progress of research.

As mentioned previously, the recently enacted Federal Grant and Cooperative Agreement Act of 1977 is intended to provide clarification for such matters. The implications of the Act in the management of federal assistance programs have been explored in a study mandated by the Act and conducted by the Office of Management and Budget (OMB). The final report of this study[6] became available just as the present Commission report was being completed. The Commission has consequently not had an opportunity to study it carefully and to comment on it in this report. We are hopeful that the Act and the study report will have a positive effect on sponsored research agreements between the government and the universities.

The Federal Grant and Cooperative Agreement Act makes clear that the distinction between "assistance" and "procurement" should be reflected in the type of funding instrument used. However, there is some concern in the research community that cooperative agreements as defined in the Act may become a common form of supporting basic research in the universities with the implication of much more widespread federal involvement in the conduct of the research. There is also concern that Department of Defense agreements will become more restrictive if that Department remains unwilling to use grants rather than contracts for support of basic research. One key to the problem is the development of a more widespread understanding and consensus about the nature and expectations of the grant relationship. In supporting research by way of grants, the government is *not* bestowing gifts, favors, or charity on institutions or individuals. It is building and renewing public investment in an important public asset. The government receives a valuable return for its investment.

Research grants are, for the most part, provided on a cost-reimbursement basis. As the Commission pointed out in its report on accountability,[7] despite differences in the nature and purpose of grants and contracts, both types of instruments are subject to the same set of cost principles. These cost principles were adapted from commercial cost principles and fit a procurement mode. The Commission recommended in its first report that accountability requirements be carefully tailored to the nature of the activity. It may well be that the most appropriate approach for grants for basic research would be for them to be offered on a grant-in-aid basis, rather than on a cost-reimbursement basis. Such an approach would shift the emphasis from analysis of costs and examination of documentation for validation of costs to evaluation of scientific efforts and results. The stringency of the review system for renewal of support and the relatively modest sums involved mean that such an approach represents very little risk to the university or the government. It could offer substantial savings in administrative costs.

There are several important issues involved in the choice of the funding instrument to be used. These include: who (the sponsor or the investigator) defines the research problem and objectives, whether the objective is to meet a need of the Federal government itself or to pursue a broader public purpose, the extent of federal involvement in or control over performance of the work, the congruence of the administrative requirements of the agreement with the nature of the activity, and the consistency of administrative procedures applied in federal programs. The universities, the researchers, and federal agencies tend to agree that these are the important issues, but they differ as to what is the overriding issue.

For the investigator and the university, the key issue is the congruence of the scope specificity and administrative requirements with the nature of the activity. For the federal sponsor, the key issue is whether the objective is to meet a need of the government itself or to encourage pursuit of a broader public purpose.

The challenge, therefore, is to develop funding instruments and a system of guidance for their use which can simultaneously accommodate the principal concerns of both sponsor and performer. The system must also be able to accommodate the wide variety among performers.

Cost Sharing

Diversity in cost-sharing requirements and differences in underlying rationale cause complications. The requirement for cost sharing in federal research grants to educational institutions is embodied in a provision in congressional appropriation acts for HEW, DOD, and the independent agencies:

> None of the funds provided herein shall be used to pay any recipient of a grant for the conduct of a research project an amount equal to as much as the entire cost of such project.

This requirement originally was introduced to replace statutory limitations on the amount of indirect costs educational institutions could recover. The intended purpose was to help assure efficient utilization of resources available and to promote sound planning and prudent fiscal policies.

Now almost fifteen years later, federal agencies differ significantly in how the cost-sharing requirement is imposed, what purposes it is intended to serve, and to what extent the institution must share in the costs. Some agencies provide for sharing on an institution-wide basis, negotiating institutional cost-sharing agreements. Others require documentation of cost participation on a grant by grant basis. Programs within agencies will also vary in the amount and purpose of the cost sharing required. For the National Science Foundation, the rule of thumb has been more than one percent cost sharing on research grants, but as high as 50 to 60 percent in equipment grant programs. In the NEH Research Division obligation varies from program to program, with minimum levels now ranging from 20 to 40 percent. NASA recently implemented a much less stringent interpretation of the legislative cost-sharing requirement based on discussions of legislative intent.

In recent years, spreading limited federal resources has emerged as a rationale for cost sharing. In some agency programs it seems to be the primary rationale. Cost sharing also serves as an "entrance fee" for participation in the federally sponsored research support system. In some cases, this entrance fee rationale slides into a form of cost competition. But true cost competition is not involved, since the competing proposals address not a single set of objectives but different, investigator-identified research problems.

These variations in rationale and requirements complicate the government-university research relationships and lead to some of the misunderstandings which are presently undermining its effectiveness.

In 1972, the Government Procurement Commission recommended to Congress that cost sharing be eliminated on research and development projects, except in cases where the performer of the project would clearly benefit, for example, through economic benefits or commercial sales. That Commission further recommended that the decision with respect to placement of research and development contracts or grants should *not* be influenced by potential involvement in cost sharing.

Later, in recognition of the costly and unproductive paperwork burden associated with documentation of cost sharing, the Federal Paperwork Commission reiterated the Government Procurement Commission recommendation to remove the requirement.

Despite these recommendations, cost-sharing requirements persist. Furthermore, the extent of cost sharing required seems to increase gradually, and the recently revised OMB Circular A-21 which sets out cost principles governing research awards imposes additional documentation requirements.

The question must be asked: Do present cost-sharing practices represent a wise approach for the support of research and for the health of the government-university relationship?

Indirect Costs

The administration of indirect cost reimbursement can be improved. A source of substantial strain within universities supported by federal research funds, and also more generally within the government-university research relationship, is the administration of indirect cost reimbursement. The indirect costs are real, the mechanism for computing indirect cost rates is spelled out in detail in OMB Circular A-21, and the rates which prevail are negotiated and agreed on by the university and the designated federal auditing agency. Nonetheless, many university researchers and federal program officers view university administrations' efforts to recover indirect costs as diverting research funds for purposes unrelated to research. The problem is exacerbated by indirect cost averaging on a university-wide basis. This puts a mathematician with little demand for overhead

services on the same basis as the physicist with heavy demands for technical and other services which burden the indirect cost pool. While this problem is partly a university one, the Federal government in its administration of research funds can do more than anyone else to relieve the strain and to make the entire research effort run more smoothly.

In the National Institutes of Health, indirect costs are reimbursed separately from direct costs. Consequently, indirect cost reimbursements are normally not perceived to be in direct competition with direct research funds by investigators, agency program officers, and peer reviewers. The Commission believes that if other agencies, in particular the National Science Foundation, adopted the NIH approach to indirect cost reimbursement, substantial strain within the government-university research relationship could be eliminated.

Proposal Preparation and Review

Research manpower resources to prepare and review proposals are substantial and growing. One of the limitations of the individual project grant mechanism for support of research is the fact that considerable research manpower is required for the preparation and review of proposals. The research productivity cost of this burden must be considered. Various alternative mechanisms of support have been considered to reduce this cost and to meet other objectives. Some of these are now available, as described earlier in this document. The individual project system, however, has always enjoyed strong support among the investigators themselves. Several evaluations of the system have been undertaken over the years, with the principal result being an endorsement of the virtues of the system. The separately published results[8] of the Commission's review and discussions confirms that conclusion, but indicates that adjustments to that system should be made to reduce the effort consumed by proposal preparation and review. Recent federal agency moves to limit the length of proposals will help. Adjustments in the length of support period and streamlining the process for requesting continuation or renewal of support should also be explored.

Collaboration

Interdisciplinary and industry collaborative research need more effective approaches. While funding mechanisms and funding instruments are not the principal barrier to improvement of our capacity for effective interdisciplinary research and university-industry research collaboration, new concepts in funding mechanisms and instruments may be required to accommodate efforts toward these ends. Experimentation with new approaches offers the opportunity to explore and test the results.

Manpower Development

The close relationship of performance and manpower development justifies their linkage in research funding. Research experience has become an essential part of the education of students who will become scientists or scholars and also of many who will enter applied science or other research professions.

The involvement of students as research assistants on faculty research projects provides needed assistance to the faculty while giving valuable experience to the students. The value of research participation to students is enhanced when the projects address problems of high significance, as is often the case with federally supported research. The students provide a stimulus which enhances the research environment in universities. They represent a continuing flow of new minds. They bring questions, suggestions, challenges, and new ways of looking at data. Their thinking is not yet habitual. Their exposure to many new topics makes them able to see relationships and to draw analogies which experienced researchers can miss. Furthermore, the act of teaching by faculty members, whether in the classroom or in research supervision, forces reexamination of fundamentals and deepens the teacher's understanding.

Fluctuations in federal research support require an elasticity in the personnel pool which is partly provided by the availability of graduate students. Regular employees, such as research technicians, require a more stable employment structure and are not as adaptable to varying levels of support as are graduate students.

For all these reasons, therefore, the coupling of research and graduate education is clearly advantageous.

In addition to this substantive coupling, there is another facet of the symbiosis between research and graduate education which is related to funding mechanisms. Federal research training grants have the primary objective of developing research manpower, but they also contribute to research productivity through the trainee's research. Federal research grants have the primary objective of research performance, but also contribute to research manpower development through the participation of students as research assistants. It is therefore

important that Congress, federal agencies, and universities recognize that adjustments in either of these mechanisms to address changing priorities related to their principal purpose will have impact beyond that immediately intended. They must also recognize the value and complexity of the symbiosis when issues of scientific and financial accountability are addressed.

University-Based Research Centers: A Growing Issue

In addition to the problems which the Commission has identified in the array of funding mechanisms and within the funding mechanisms themselves, attention should be drawn to a related issue which deserves more careful consideration from both the government and the research universities. This is the evolving role of university-based research centers in the national research enterprise.

For the most part, university scientists have combined teaching and research duties, with relatively few academic scientists working in purely research roles. With the decline in the size of the college age population and the consequent decline in the demand for teachers of science in the universities, academic job opportunities for young scientists inevitably will be limited for some time. This raises the question of maintaining the scientific research capability of our country at an adequate level in the face of potential declines in the capability of one of the current major performers and in the supply of young researchers.

There are several possible ways to deal with this issue. One way would be to shift more of the basic research burden to industrial laboratories, but this does not seem to be a likely possibility. With a few notable exceptions, industrial research and development laboratories have shown little interest in supporting or performing basic research.

Another way is to develop a series of research institutes outside the universities, sponsored by the Federal government, much as is done in West Germany. While this can be an effective means for accomplishing research, as the Germans have demonstrated, it divorces research from teaching. One of the advantages of the American system as it has been in the past is the close association of research with teaching and particularly with the teaching of graduate students. Not only is the scientific output of research scientists plus postdoctoral fellows plus graduate students greater than would be the research output of research scientists alone, but the system also produces the next generation of scientists in an effective apprenticeship setting. There has also been a substantial national investment in research facilities in the universities. It seems unwise to allow this investment to lie fallow.

A third possibility is the development of increased numbers of research institutes in university settings. This would keep research and teaching close together, with all the attendant advantages. However, a number of difficulties are already apparent in universities where such research institutes exist in significant numbers. They tend to result in the creation of a parallel-track staff of researchers who do not share the responsibilities and prerogatives of the regular faculty who teach and participate in university governance in addition to doing research. Counterproductive conflicts between these two classes of researcher can arise, as well as conflicts between the research institutes and disciplinary departments.

Another set of problems results from the necessity of developing administrative procedures for research institutes which in many ways differ from and conflict with the traditional decentralized administrative structures of universities.

The general question of how research universities can and should continue to play their role in the national research enterprise, in the face of coming economic and demographic strains, without sacrificing the structural characteristics which have been responsible for their past success, is a serious one deserving careful attention by both government and the research universities.

Conclusions

The Commission has studied the system of federal funding mechanisms used in the distribution of the nearly $4 billion per year supporting university-based research. It has examined the strains which appear to exist in this system in hopes of identifying modifications which will improve its effectiveness. On the basis of the Commission's interviews with many researchers and administrators from both the government and the universities, as well as its review of materials developed by others on this matter, the Commission has reached the following conclusions:

1. *Essential Elements*

For effective functioning of the research support system, the following key elements are essential:

- Fundamental agreement about the nature and purpose of the government-university relationship
- Diversity of sources, mechanisms, and instruments for research support and diversity of research performers
- Investment in both near-term and long-term objectives
- Provision for beginning new ventures and sustaining research capacity
- Continuity and stability of support
- Flexibility for effective technical and fiscal management
- Opportunities for new investigators
- Enlistment and training of future investigators.

2. *Character of Agreements*

Investigators, the universities, and the government need to develop a better understanding of the nature of the government-university research relationship and the purpose of the specific research agreements they make. The terms of such specific agreements must (a) contribute to the welfare of the relationship, (b) reflect the purpose of the agreement (whether procurement or assistance), (c) fit the nature of the activity to be undertaken, (d) call on the capacity of the recipient for responsible management of the activity, and (e) accommodate the diversity of the research performers and sponsors.

3. *Unresolved Problems in a Basically Sound System*

While the current system of research support mechanisms is basically sound, there are unmet needs which must be addressed and problems which need to be resolved. These include:

- A rapidly developing equipment inadequacy problem exists.
- Provision for new research initiatives and for sustaining research capacity is inadequate.
- Institutional support for research in the humanities and social sciences is eroding.
- Continuity and stability are often missing.
- Flexibility is frequently inhibited.
- Procurement procedures are used inappropriately in research support.
- Diversity in cost-sharing requirements and differences in underlying rationale complicate the government-university research relationship.
- Administration of indirect cost reimbursement can be improved.
- The fraction of the nation's research manpower resources being used to prepare and review proposals for research support is substantial and growing.

- Effective ways of approaching interdisciplinary research and collaborative research between universities and industry still need development.
- Complexity of the symbiosis between support of research and development of research manpower is not fully appreciated; nor have we yet learned how to control it successfully.

4. Continuing Experiments

Continuing experimentation with new and modified funding mechanisms and funding instruments should be encouraged to improve the research support system. The effectiveness of the system depends upon its adaptability to changing needs and a changing environment. The development and implementation of new concepts and new modes of research support therefore should be a permanent item on the agendas of federal agencies and the universities.

Examples of areas in which experimentation could now be useful include:

- Methods to improve the stability and continuity of support
- Ways to reduce the burden of proposal preparation and review
- Ways to increase research flexibility and reduce administrative costs.

5. Mismatched Expectations

In the government-university research relationship, a small number of unresolved issues is frequently the source of mismatched expectations and misunderstandings. Even though some of these issues may be clearly resolved at the policy level, they persist at the operating level. Examples of such unresolved issues include:

- The proper locus of control for the most effective basic research
- The extent to which support of research in universities is intended to serve the dual role of meeting research needs and developing research manpower
- How and why the universities and the government should share the costs of basic research.

6. Complexity

The government-university research enterprise is a complex, multi-faceted system. Unfortunately, few participants in the enterprise comprehend the whole system or recognize the extent of its complexity. It is easy, therefore, for its problems to be oversimplified and for the potential impact of their solutions to be misjudged. One example is the complexity of the relationship among the nature and balance among the funding mechanisms, research productivity, and the development of research manpower.

7. A Forum: Refining the Concept

In its first paper, *Accountability: Restoring the Quality of the Partnership*, issued in March 1980, the Commission presented a preliminary suggestion for a Forum of individuals concerned with the government-university research partnership. This was presented in a separate section of the report, entitled, "Toward Improvement: An Evolution." The separate presentation emphasized the view that the Forum concept related to all the work of the Commission, not only to accountability issues. The Forum would "see the relationship *as a whole*, and guide its evolution in directions that assure its strength and vitality." The Forum suggestion was offered to stimulate ideas and discussion. The proposal is:

> The Commission suggests the establishment of a new and independent Forum, as an experiment for five years. The Forum should provide a non-adversarial setting for persons from the public, Congress, universities, and federal agencies to watch over the government-university relationship and guide its evolution.

Since publishing this suggestion, response to the concept has come from many sources, including agencies, associations, the Congress, and universities. Most reactions are highly positive and strongly supportive. Considerable discussion as to the proper mission, locus, organization, membership, and activities of a Forum has begun.

The Commission is gratified with the character of this response, as it believes that broad and careful consideration throughout the government-university research community must precede the establishment of a suc-

cessful body in response to its suggestion. In order to maintain and expand the dialogue on the Forum proposal, and to report the supportive character of the initial reaction, the Commission reiterates the suggestion in this report.

Based on these developments, the Commission concludes that further refinement of the Forum proposal should continue through discussion and appropriate actions by interested parties.

Recommendations

1. Equipment Obsolescence

The Commission recommends that the federal agencies and the universities adapt funding mechanisms and improve priority-setting strategies to solve the growing problem of research equipment obsolescence.

The Commission has considered the deteriorating research equipment situation. Steps must be taken soon to address this problem if the American research enterprise is to remain efficient and competitive internationally. Ideally, new funds would be appropriated to this end, but in a period of level or declining funding, there is no way to approach the problem without diverting a fraction of the funds presently going into support of people engaged in research activity. Undesirable as such diversion might be, the Commission believes it is necessary.

The responsibility for allocating the necessary funds falls on the universities, the government, and the scientific community. The universities can cope with this massive problem only in modest ways, but it is important for them to accept as much of the responsibility as possible. Federal agencies should place a clear priority on responding to well justified equipment requests through the regular funding mechanisms. This alone, however, will not be enough to halt the rapid deterioration of the national research equipment inventory. The Commission believes that for at least the next few years special supplementary measures will be necessary. Targeted equipment grant programs such as the ongoing NSF Research Instrumentation Program in chemistry and the recent one-time program in the National Institute of General Medical Sciences (NIGMS) offer models that should be adapted by other agencies.

Since the problem is so large, it is important to establish priorities among equipment needs. The knowledge and experience of the scientific community is essential to help the government and the universities establish priorities and to develop plans for equipment acquisition and use. The High Energy Physics Advisory Panel (HEPAP) and the Nuclear Science Advisory Committee (NUSAC) have played central roles in their fields in establishing national priorities for construction of large experimental facilities. Similar functions have been served by *ad hoc* groups in other fields, as in the case of the Dicke Committee in radioastronomy several years ago. These successful examples lead the Commission to suggest that such groups be established in other fields to advise the government and the universities on priorities among equipment needs and between equipment needs and other competing needs.

The government and the universities must develop incentives and strategies for effective sharing of equipment at both the local and regional levels. They must remove the obstacles to sharing which presently result from certain accountability requirements. They must also recognize that sharing of equipment can be constrained by the cost of renovation to provide co-location of users, by highly specialized use, and by the impracticality of transporting unstable experimental samples or auxiliary equipment to centralized or remote sites. Researchers must overcome their natural "territorial instincts" in acquisition and use of research equipment. It is especially important to include good cost-benefit analyses in the development of sharing strategies so that the advantages of sharing acquisition and maintenance costs are not overshadowed by administrative and operating costs.

Because it is so important to divert the minimum possible amount of money away from current research support to equipment acquisition, imaginative funding devices also are called for. Consideration should be given to debt financing ("mortgages"), with retirement of the debt and interest through use charges to sponsored projects.[9] We believe that research supporting agencies should make clear to investigators, peer reviewers, and universities the acceptability of equipment use charges. These charges would allow timely acquisition of important pieces of equipment while distributing the cost over a convenient time period. In certain situations, particularly in public institutions, it may be possible to promote issuance of revenue bonds. Revolving lines of credit at banks or outright loans may be appropriate. Lease or lease-purchase arrangements offer other alternatives for facilitating equipment acquisition.

Substantial interest charges will characterize many of these approaches and, while reimbursement of interest charges can now sometimes be negotiated in occasional cases, revision of OMB Circular A-21 to permit routine reimbursement of interest charges would greatly facilitate the debt-financing approach to the equipment problem.

2. Stability, Continuity, and Flexibility

The Commission recommends that Congress and the federal agencies develop and implement means to increase the stability, continuity, and flexibility of research support while retaining the capacity to respond to changing national priorities. The Commission offers several specific recommendations to this end.

Basic research is a relatively long-term enterprise, characterized by cumulative building on previous work in the same or related fields. While the continuing opportunity to initiate new basic research projects is an essential element in the overall national research program, changes in national needs have far more impact on applied research and development directions than on basic research. For this reason, provisions for the continuity and stability which enhance basic research productivity can be implemented with little or no cost in overall program flexibility.

Duration of assured support is one critical factor for research planning. Frequent competitive review in basic research is often unnecessary. It diverts investigator efforts from active research to proposal writing and review. It complicates the long-term planning by both the investigator and the institution which is necessary for the wise use of resources, facilities, and personnel.

Some agencies, notably NSF and NIH, have designed mechanisms to provide multi-year grants so that research is subjected to the full competitive review process only every two or three years. Some agencies, however, continue to make only one-year awards even where the actual turnover among supported investigators is small. For some agencies, the limitation to one-year awards is based on the one-year congressional appropriation cycle and the agency experience of considerable fluctuation in the magnitude of funds appropriated for basic research. Therefore:

(a) The Commission recommends that Congress consider making a transition to a two-year appropriation cycle for those agencies and components of agencies which support basic research.*

Further:

(b) The Commission recommends that those agencies and components of agencies which support basic research lengthen the average duration of their basic research support agreements to at least two and preferably three years, if they have not already done so.

Also:

(c) The Commission recommends that agencies experiment with authorizing program officers to award a limited number of non-renewable extensions of support at approximately the same level, without the full renewal proposal submission and peer review.

Such extensions would be reserved for those projects which (a) are natural extensions of the previously approved project, (b) are progressing well, and (c) need continuing support. In such cases full competitive review is an unnecessary diversion and wastes the resources of the government, the university, and the researcher.

Another critical factor for research planning is the extent of advance notice of decisions on future research support. In the course of its work, the Commission has encountered many reports of delays in notice of renewal support for ongoing research, notwithstanding that renewal proposals were submitted on time and well before the end of the grant period. Some delays are extensive, lasting weeks and even months after the end of previous award periods. The Commission also learned that notices of new awards and of renewals or nonrenewals are often received within days of their effective dates, thus allowing little or no time for orderly planning. Delayed or inadequate notice of decisions on future support imposes serious burdens on performing institutions and researchers. It forces institutions to underwrite federally sponsored research programs without assurance of eventual reimbursement or compensation for foregone interest on the capital advanced, and it slows initiation of new projects.

This problem sometimes results from delays in the congressional appropriations process. To some extent, short lead times in notices of support decisions are a result of efforts to minimize the time between the submission of a proposal and the initiation of the work. This is clearly the case where an external peer review process is used. However, a significant part of the problem appears to be due simply to administrative inadequacies in the agencies.

For individual research project grants or contracts, an average duration of two to three years of support would allow reasonable stability, provided it is coupled with an adequate, advance notice of the decision on future support. Therefore:

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*Federal agencies typically operate on a one-year appropriation cycle. Most agencies must expend their funds in the year for which they are appropriated. NSF funds are available for expenditure for a two-year period. This extended availability does *not* contribute as significantly to a solution as would a biennial cycle.

(d) The Commission recommends the introduction of incentives for funding agencies to provide more timely notices of awards.

The Commission offers two specific suggestions: (1) three-month extension of research support at the same level would be provided to continuation or renewal proposals if the principal investigator meets the agency deadline and the agency fails to provide notice of the funding decision at least thirty days prior to the end of the current award period; (2) imputed interest costs would be allowed for use of institutional funds to continue a project for which the agency award is so delayed.

(e) The Commission recommends that agencies which fund large research programs build in forward-funding mechanisms or devise new ways to cushion the impact of termination of support.

For individual research project grants or contracts an average duration of two to three years provides reasonable stability. While nonrenewal of support for such a project is always disappointing, the impact is usually quite localized. Nonrenewal of support for a large research program grant or a center grant, however, has a significant impact on both individuals and the institution and requires considerable advance planning. Special mechanisms to provide adequate lead time for an orderly phase-out are necessary to limit destructive disruption. Such mechanisms have been used successfully by federal agencies in the past. For example, NASA and DOD have used the step-funding and roll-forward funding mechanisms to good advantage.

3. Research Capacity and Initiatives

The Commission recommends that the government and the universities work together to develop or adapt a funding mechanism to sustain the research capacity of universities, especially their capacity to undertake new research initiatives.

A responsibly managed research enterprise, whether at the national or the institutional level, must provide for sustaining research capacity and for seed money to support new research thrusts. Although the present system of mechanisms for funding university research is supple and diverse, it fails to provide adequately for these needs. The Commission recommends that the government and the universities together remedy this lack.

The present heavy reliance on individual research project support in the government-university research enterprise encourages and often demands a rather fine grained compartmentalization of both scientific effort and funding. This, in turn, leads to voids and discontinuities in the funding available from external sources to a research university, to the detriment of smooth and efficient functioning of its research effort. For example, pilot projects must often precede project support. Emergencies and unexpected opportunities arise. Facilities need updating for contemporary research purposes. New investigators must get their research programs launched. Shared research resources must be developed and maintained throughout the ebb and flow of external project support. Provision for these costs is rarely made available through the regular funding mechanisms.

In the past, when the magnitude of the total research effort of the research universities corresponded to a relatively small fraction of their budgets and they were less burdened by financial pressures than they commonly are now, universities frequently found it possible to compensate for these voids and discontinuities from their own funds, as a natural part of meeting their responsibilities for support of research. Today the institutions' capacities fall far short of meeting the needs associated with their greatly increased participation in federally sponsored research. Furthermore, the gap between these needs and the university capacity to meet them is growing. The research programs of a typical research university require tens of millions of dollars annually and may account for a quarter of the institutional budget. At a time when all sources of institutional income are severely restricted, it is extremely difficult for a research university to find the resources to fill substantial voids left by current federal funding mechanisms. This burden lies heaviest on those institutions with the largest commitments to the government-university research partnership.

What is needed is a funding mechanism which can serve as a kind of balance wheel to keep a university research effort functioning efficiently despite the irregular and fluctuating forces caused by other funding mechanisms. We have chosen to label this new mechanism "research capacity support," although other terms would be equally appropriate. We envision a mechanism which would provide funding at a level related to the total federal research and development funding of the institution. Coupling the level of research capacity support to the total federal support provides a tie to the existing quality assurance and selection processes and a connection between need and response. The level of support should probably lie in the range of one to three percent of total federal research support. The analysis required to establish the appropriate level was beyond the resources of the

Commission but will need to be undertaken. Because decisions about the needs to be addressed and priorities among them can adequately and perhaps optimally be made at the local level, research capacity support funds would be allocated by the institution for purposes consistent with general principles established by the Federal government in consultation with the research universities. These principles should include:

1. Research capacity support funds would be used to meet research needs which cannot adequately be met through other funding mechanisms.
2. The distribution of research capacity support among research fields should correspond generally to the pattern of federal research support provided the institution through other funding mechanisms.
3. Allocation of research capacity support funds would emphasize maintenance of research capacity through, for instance, provision of equipment or facilities for shared use by many investigators, and provision of venture funding for new research undertakings.
4. The allocation system would be designed by each institution to suit its own structure, but should meet general quality assurance and accountability standards established by the government in consultation with the research universities.

This research capacity support mechanism should include a provision for demonstration of the institutional commitment to research through a requirement that the federal funds be supplemented by a significant allocation of institutional funds; something on the order of 10 percent of the federally provided research capacity support funds would seem appropriate. It should be pointed out that this institutional participation would also be responsive to government interest in institutional cost sharing. The research universities have long pressed for elimination of cost-sharing requirements imposed by the Congress and by the agencies, not because they oppose cost sharing *per se*, but because they oppose the administrative burden which accompanies these requirements under present systems. Institutional participation in research capacity support funding would constitute substar tial cost sharing in a simply documentable fashion.

The Commission wishes to emphasize that it does *not* envision that the creation of a research capacity support mechanism will necessitate "add-on" appropriation of funds over and above normal federal research funding levels. It recognizes that the ability of the Federal government to support research in universities is and will continue to be severely constrained, and the use of such a new funding mechanism can most likely occur only at the expense of other mechanisms. Under current economic conditions, such a mechanism is needed to help universities plan and manage their research efforts. This would allow universities to provide the best research possible with the available funds, maximizing efficiency and minimizing administrative and overhead costs.

4. Assistance As the Predominant Approach

The Commission recommends that the Federal government and the universities adopt the policy that assistance rather than procurement is the appropriate mode for support of university research, except where unusual circumstances specifically justify the use of the procurement mode.

The Federal Grant and Cooperative Agreement Act (Public Law 95-224) distinguishes two modes of federal funding for work performed by non-federal organizations, assistance and procurement. It further defines three types of funding agreements, *viz.*, grants, cooperative agreements, and contracts. The Commission views this Act as one starting point for evolving a better system of funding mechanisms for support of university research and development. In university research, it is important to recognize that activity labels such as "basic research" or "applied research," and funding instrument labels such as "grant," "cooperative agreement," and "contract" should not themselves be the determining factor for the choice of the terms of the agreement.

For the researcher and the university, the key issue is the congruence of the specificity of the scope of the agreement and of administrative requirements with the nature of the activity. For the federal sponsor, the key issue is whether the objective is to meet a need of the government itself or to encourage pursuit of a broader public purpose.

The challenge, therefore, is to develop funding instruments and a system of guidance for their use which can simultaneously accommodate the principal concerns of both sponsor and performer. Such a system must also be able to accommodate the wide variety among performers.

The Commission believes that, for almost all university research activities, assistance rather than procurement is the appropriate support mode. Inappropriate use of procurement procedures creates unnecessary misunder-

standings and administrative difficulties for federal agencies and universities alike. This Commission recommendation would require that funding mechanisms used to support university research be tailored to the assistance mode rather than the procurement mode, except in cases where the specific circumstances clearly demand the procurement mode. In other words, selection of the procurement mode ought to require a conscious decision based on explicit justification.

This recommendation is corollary to Recommendation 2a of the Commission's first report on accountability, which calls for development of a "new system for accountability tailored to the nature of the activity being sponsored and based on a set of minimum core requirements applicable to all research agreements. The core requirements would be sufficient for all basic research. Further requirements would be added only for activities of a pronounced procurement character."

5. Experimentation with Mechanisms

The Commission recommends experimentation with new concepts in funding mechanisms as the government-university research relationship evolves. In particular, the Commission recommends experimentation with grants-in-aid managed at the local level.

One objective of the Commission in making this recommendation is to reduce administrative complexity and to focus emphasis on scientific accountability as opposed to excessively detailed fiscal accountability. The extraordinary care given to the selection of research projects to be funded, and the critical role which past performance plays in decision for renewal of support, provide a reliable test of scientific accountability, and provide a good opportunity to experiment with alternate fiscal accountability approaches. In the Commission report on accountability, Recommendation 8 calls for delegation of more authority to the universities for budget and management decisions under sponsored agreements.

The Commission urges experimentation with another approach to the same problem, *viz.*, use of grants-in-aid. This would be an award made in response to a normal research proposal including a detailed budget like the current NSF and NIH proposals, but with the accounting to the Federal government limited to scientific reporting, and with the fiscal management delegated to the investigator and his institution. The Commission believes that the incentives for wise management of resources which are inherent in the research funding system reduces the risk of fraud, abuse, or inefficiency to a minimal level.

We suggest that the experiment be designed to test this approach in different institutions and in different research disciplines, beginning at modest support levels and increasing support if the experiment proves successful.

The Commission recognizes that such an approach shifts the locus of budget control from the government to the university and that this shift may introduce intra-university strains. The Commission believes, however, that such strains can be minimized by careful cooperative planning and that the advantages of increased flexibility and reduction in administrative burdens will outweigh any residual difficulty.

The Commission recognizes that this new mechanism might require some adjustments for the calculation of indirect costs, but we believe these will be modest and manageable. The Commission Recommendation 5 in its accountability report for a "standard deduction"—an optional method of deriving the indirect cost component for faculty indirect cost activity—removes a barrier which previously thwarted experimentation with the grant-in-aid approach.

6. Cooperation within Institutions

The Commission recommends that the universities and the government seek ways to promote intra-institutional cooperation in all aspects of research operation. The Commission offers some specific recommendations toward this objective.

There are several ways in which the present government-university research system tends to pit research scientists against their own institutions and to work against cooperation within the institutions. The heavy use of the individual research project support mechanism, for all its strengths for selection of research, has some disadvantages. The combination of its dependency on individual entrepreneurship with its compartmentalization of research support can lead investigators to resist sharing of equipment and other resources. The inability of the universities to provide from their own resources the research equipment and facilities commensurate with the present level of their research activities places the federal agencies and their project officers, instead of the

institution, in the role of primary sponsor. Agency program officers occasionally circumvent the government-university contractual relationship and attempt to negotiate directly with the principal investigator on matters which are an institutional concern. These circumstances produce divided loyalties, introduce friction between the investigator and university administrative officers, and undermine the stewardship capacity of the institution. Accountability problems can result from these strains.

The Commission repeats in this report one of the recommendations made in its report on accountability:

(a) The Commission recommends that Congress authorize and the agencies develop arrangements for aggregating research projects for post-award administrative purposes.

Implementation of that recommendation would address a number of current problems, including the problem of arbitrary barriers to sharing costs among related projects and disincentives for intra-institutional cooperation. The aggregation the Commission proposed would preserve fully the appropriate control for the principal investigator.

(b) The Commission recommends that the universities make concerted efforts to reduce internal friction and misunderstanding about indirect costs through education and full discussion of issues.

A major source of friction between investigators and their institutions is the use of federal funds to reimburse a portion of the university's indirect costs. Many institutions have failed to provide adequate information to their research personnel about the nature of indirect costs and the relevance of these charges to the conduct of research. Even where such information has been provided, some investigators continue to believe that such reimbursement represents undeserved "profit" by the universities. Others believe that the averaging method used in distributing indirect costs among projects represents an unfair tradeoff between the cost of more precise accounting and the inequities inevitable in the use of an averaging approach. These concerns not only affect intra-institutional relationships but also influence the thinking in the peer review groups which help select the research to be funded.

(c) The Commission recommends that the method used by the National Institutes of Health for reimbursing indirect costs be adopted by NSF and other agencies which interact significantly with universities.

Since attitudinal change is not a rapid process, some more immediate measures to reduce unnecessary strains seem wise. Under the NIH method, funds are specifically earmarked for reimbursement of the indirect costs of research at the agency level and are segregated from funds for support of the direct costs of research. The funds which are granted for a specific research project then are not immediately influenced by the magnitude of the indirect cost rate or a change in that rate. This decoupling of indirect cost considerations from direct cost considerations is also helpful because it reduces the temptation to make meaningless or misleading comparisons of the indirect cost rates of different institutions.

7. Cost-Sharing and Matching Requirements

The Commission recommends that Congress, the agencies, and the universities reexamine the rationale for cost-sharing and matching requirements in federal programs for support of research in universities to assure that any such requirements are constructive in furthering the mutual objectives of the government-university research relationship.

Formal statutory requirements for cost sharing on research grants were introduced in the mid-1960s when the arbitrary ceiling on indirect cost recovery was removed. The rationale presented then was that such cost sharing would serve as an incentive for wise choices on which research to undertake, for efficient operation, and for cost control. Such cost sharing was also considered appropriate since research is one of the university's regular functions.

As the number and kind of federal programs supporting research and other activities in universities has increased and as the federal programs providing support for activities of state and local governments have grown, expectations and demands for cost sharing or matching have grown and changed. Practices used in one program have been adopted in other programs. In some programs, the principal rationale seems to be to help establish priorities among applicants by testing the grantees' relative commitment, as evidenced by cost sharing. In some programs, the primary impetus for the cost-sharing requirement is to stretch limited federal resources to respond to more applicants. In some programs, the program objective and responsibility for meeting it are shared, and cost sharing reflects this mutuality of interest. In other programs, the cost-sharing requirement is intended to

serve as an incentive to stimulate the private sector to provide support. In some situations, however, cost sharing seems to be simply an "entrance fee" to participation in the government-university research relationship. The variation in rationale and requirements for cost sharing complicate the government-university research relationship and undermine its effectiveness.

The Government Procurement Commission recommended elimination of cost sharing from research and development projects except in cases where the performer would clearly benefit, for example, through economic benefits or commercial sales. That Commission further recommended that the decision with respect to placement of research and development contracts or grants should *not* be influenced by potential involvement in cost sharing. The Federal Paperwork Commission reiterated the Government Procurement Commission recommendation because of the costly and unproductive paperwork burden associated with documentation of cost sharing. Despite these recommendations, the requirement persists, new documentation requirements have recently been added, and the amount of cost sharing required seems to be increasing.

In its first report on accountability, the Commission urged Congress to remove the statutory requirement for cost sharing so that the burden of documentation could be removed. The Commission recognized that whether or not there is a statutory requirement, universities and the government will continue to share the costs of basic research.

The Commission also recognizes that it will be increasingly tempting for federal agencies to try to spread resources by requiring greater cost sharing. The resiliency of the universities is greatly diminished and cannot support such demands. Therefore, Congress, the agencies, and the universities need to reexamine the rationale and requirements for cost sharing in federal programs for support of research in universities to make sure that only constructive and necessary requirements are imposed.

8. Additional Science Indicators

The Commission recommends that the Office of Science and Technology Policy and the National Science Foundation (a) develop, employ, and report additional science indicators which reflect the balance and diversity of federal research funding programs and (b) encourage the general use of these indicators in research policy development and planning by government and universities alike.

The Commission has studied the range of existing research funding mechanisms, from individual research project grants to large block grants and institutional grants. It has considered the spectrum of federal funding agencies and the range of research styles from what is known as "little science" to "big science." It is convinced that the diversity of funding mechanisms and agencies which now exists in the United States is a crucial element in the strength of American science. It judges that the present balance among agencies and mechanisms and between little science and big science is not dangerously far from optimum. However, the Commission also recognizes that the degree of diversity and the conditions of balance depend on scientific, economic, and political circumstances, and therefore vary with time. A proper awareness of these factors is essential to government and university policy makers.

The Commission does not consider itself to be in a position to suggest which way the present balance might be shifted. It does believe that more diversity would be far preferable to less. But most of all, the Commission stresses the importance of a general awareness of the state of balance and diversity in the government-university research relationship. This will require information and indicators which reflect the distribution of federal research support across the many different types of funding mechanisms and the variation of the distribution with time. Table I of this report is an example of such an indicator. These should be developed at a national aggregate level and also within individual scientific fields and within federal agencies. Such distributions can be useful indicators of evolving national research policies. These indicators are not commonly available at present.

9. Growth of Research Centers and Institutes in Universities

The Commission recommends that the research universities, individually and collectively, examine carefully the implications for university development, structure, and governance of the growth of university-associated research centers and institutes.

The research universities of the nation face many difficult questions as they confront the financial and demographic realities of the remaining two decades of the twentieth century. Among these is the question whether the universities will find it desirable or possible to maintain their positions as the principal performers of basic

research within the national research and development enterprise. This is also a crucial question for the Federal government. If the universities' contributions to the national research effort were to wane while national requirements for research continued to be strong, the government would need to turn to other performers. There are many good reasons why the universities should strive to maintain their capabilities as research performers. There are also cogent reasons to believe that if they are to succeed in doing so, they may need to make some fundamental adjustments in their character. For example, federally funded research and development centers staffed by nonfaculty researchers may become much more prominent features of research university campuses than they now are. If this occurs, new conflicts and pressures will surely arise within the universities to develop the role of nonfaculty researchers in the university governance structures.

The Commission believes that few universities have given adequate consideration to the possibilities posed by such questions and strongly recommends that they do so. We suggest that the major university associations establish a task group to examine the issues, and that consideration be given to organizing a workshop or conference on the subject to encourage widespread discussion and planning within and among research universities.

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Appendix II: Sources

The Commission is indebted to the many persons who have provided information and advice, and it wishes to acknowledge its appreciation for their efforts. Invited expert witnesses have testified on the issues within the Commission's purview at its monthly meetings; open hearings have been held on five university campuses; subcommittees have met with individuals and groups from the Federal government; and members and staff have attended or made presentations at meetings and hearings convened by educational associations, government agencies, and Congress.

Witnesses. The following individuals presented views and gave assistance in the development of this document. The Commission wishes to emphasize that the views in this document are its own and not necessarily those of the listed individuals. This list includes meetings through March 1980.

Richard Atkinson, Director, National Science Foundation
James M. Banner, Jr., American Association for the Advancement of the Humanities
Robert Barlow, Cornell University
Carl P. Blakley, Department of Energy
Robert M. Bock, University of Wisconsin
Howard W. Bremer, University of Wisconsin
Newton Cattell, Association of American Universities
Honorable Lawton Chiles, U.S. Senator from Florida
Robert Coakley, U.S. Senate Subcommittee on Federal Spending Practices and Open Government
Tom Collins, University of California, Los Angeles
Theodore Cooper, Cornell University
Lawrence G. Crowley, Stanford University
Robert Cutler, National Science Foundation
John M. Deutch, Under Secretary, Department of Energy
Sidney Drell, Stanford Linear Accelerator Center
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Gary Evans, Department of Agriculture
Kristine Forsberg, Department of Energy
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George Gamota, Department of Defense
Howard Gobstein, General Accounting Office
Delphis C. Goldberg, U.S. House of Representatives Subcommittee on Intergovernmental Relations and Human Resources
Milton Goldberg, Council on Governmental Relations, National Association of College and University Business Officers
James Haas, Council on Library Resources, Inc.
Robert W. Hougas, University of Wisconsin
Richard F. Kaufman, U.S. Congress, Joint Economic Committee
William Kays, Stanford University
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Richard M. Knapp, Association of American Medical Colleges

Philip Kropatkin, Deputy Director, Audit Agency, Department of Health, Education, and Welfare

James Ling, Department of Energy

John Lordan, Office of Management and Budget

David Mears, University of California System

Richard Meserve, Office of Science and Technology Policy

George Millburn, Department of Defense

Bryan Mitchell, Assistant Inspector General, Department of Health, Education, and Welfare

Thomas Morgan, Association of American Medical Colleges

Morton Myers, General Accounting Office

Robert Newton, National Science Foundation

Donald Nutter, U.S. Senate Subcommittee on Health and Scientific Research

George G. Olson, Colorado State University

Gilbert S. Omenn, Office of Science and Technology Policy

George Pake, Xerox Corporation

J. Thomas Parmeter, Michigan State University

Michael Pelczar, Council of Graduate Schools of the U.S.

John D. Phillips, National Association of Independent Colleges and Universities

George Pilarinos, National Aeronautics and Space Administration and National Science Foundation

Dennis Prager, Office of Science and Technology Policy

Frank Press, Office of Science and Technology Policy

William F. Raub, National Institutes of Health

Jerold Roschwalb, National Association of State Universities and Land-Grant Colleges

Halsey L. Royden, Stanford University

Jack Sanderson, National Science Foundation

Reilly Schaefer, University of Wyoming

Helen Schroeder, National Institutes of Health

Reagan Scurlock, Council on Governmental Relations, National Association of College and University Business Officers

Richard Sessions, University of California, Los Angeles

Irving Shain, University of Wisconsin

Philip Smith, Office of Science and Technology Policy

Donald Speer, National Science Foundation

Elmer B. Staats, Comptroller General of the United States

Richard E. Stephens, Department of Energy

Eldon Taylor, Inspector General, National Aeronautics and Space Administration

Richard Tropp, Environmental Protection Agency

Thomas van der Voort, U.S. Senate Committee on Appropriations

David Wilson, University of California System

Raymond Woodrow, formerly of Princeton University

Agency Liaison. These persons have been appointed by their agencies:

Salvatore Cianci, Alcohol, Drug Abuse, and Mental Health Administration
George P. Millburn, Department of Defense
Richard E. Stephens, Department of Energy
Osmund Fundingsland, General Accounting Office
Walton Francis, Department of Health, Education, and Welfare
James R. Lawson, National Aeronautics and Space Administration
William F. Raub, National Institutes of Health
Jack Sanderson, National Science Foundation
Eliot R. Cutler, Office of Management and Budget
Philip M. Smith, Office of Science and Technology Policy

Open Hearings. Over seventy persons testified before the Commission during hearings at the national conference of the American Association for the Advancement of Science and on the campuses of the University of Alabama, Birmingham; California Institute of Technology; Stanford University; the University of Wisconsin, Madison; and the University of Utah with the Inter-Mountain University Research Association. A number of these speakers presented views on funding mechanisms in addition to other topics under consideration by the Commission.